Indian Council of Agriculture Research

The Composition of Milk

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The Indian Council of Agricultural Research

THE COMPOSITION OF MILK

PART I. COLLECTION OF DATA

BY

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THE COMPOSITION OF MILK

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Text

Page	Line	Column	For	Read
Preface .	8	..	Allahabad Agricultural Research Institute.	Allahabad Agricultural Institute
Do.	10	..	Ewin	Ewing
1	14—18	1st	after .. upon two things . .	firstly, the degree of compliance with the new standard which follows and, secondly, the difference between the quality fixed by the new standard and the quality predominating in the market at the time. Very exclusive agencies..... .....
4	22	1st	29·9	28·9
12	last	1st	or	for
13	3	2nd	0·8	10·8
14	1	1st	what s even	what is even
18	18	2nd	arge	large
23	8	2nd	$1/\bar{n}$	$\frac{1}{\sqrt{n}}$
23	33	2nd	pure change	pure chance
32	49	1st	5	·5
33	3	1st	milk standards	milk, standards
46	10	1st	not-at	not-fat
50	7	2nd	Diagrams (9·4)	Diagram (9·4)
54	10	2nd	of percentage moisture . . .	(or percentage moisture)
54	19	2nd	rtx	r_{tx}
70	25	1st	8·001 to 8·491	8·491 to 8·001
70	26	1st	8·419 to 8·842	8·842 to 8·419
70	27	1st	8·571 to 9·145	9·145 to 8·571
71	10	2nd	grouq	group
76	34	1st	S	$\bar{S}$
76	36	1st	S_1, S_g, and S_1 . . .	S_s, S_g and S_f

Tables

Table 5, page 16 . . .	Against the row "+3·00" and column "all" *for* Buffaloes, *read* "6"
Table 6, page 17 . . .	In heading, *read* "Ash" *for* "Lactose"
Table 16, page 24 . . .	Against the item, Mean for Specific Gravity for Mixed Milk of Murrah buffaloes, *read* "1·03170" *for* "1·0317"
Table 17, page 25 . . .	Against the item Mean for Percentage Calcium Oxide under Toned Milk 3·5% butter fat for Red Sindhi Cows, *read* "0·1949*" *for* "0·1949"
Table 17, page 25 . . .	Against the item Mean for Percentage Solids-not-fat under Toned Milk 3·5% butter fat of Murrah buffaloes, *read* "9·644*" *for* "9·644"
Table 24, page 30 . . .	Against North-west Frontier Province etc., under Buffalo Milk, 1st Column viz., Minimum Percentage of Milk-fat, *read* "5·0" *for* "....."
Table 24, page 30 . . .	Against North-west Frontier Province, etc. under Buffalo milk 2nd Column viz. Minimum Percentage of solids-not-fat. *read* "9·0" *for* "....."
Table 25, page 31 . . .	In the heading *read* "Samples" *for* "samples"
Table 28, page 33 . . .	Against the item Specific Gravity 1·028 under Red Sindhi *read* "·0152" *for* "·01" and "·0011" *for* "·001" respectively
Table 28, page 33 . . .	In the 3rd row under cows, *read* "·0009" *for* "[illegible]·07"
Table 28, page 33 . . .	In the 4th row under cows, *read* "·000[illegible] *for* ·00027"
Table 28 page 33 . . .	In the row for Murrah, *read* "·0001" *for* "·0006"
Table 28, page 33 . . .	In the 3rd row under Buffaloes, *read* "·0002" *for* "·000"
Table 30, page 35 . . .	Row 21 *read* "—·29*" *for* "—·29"
Table 31, page 36 . . .	In the heading, *read* "solids-not-fat" *for* "solids Cows not fat"
Table 31, page 36 . . .	In the heading *read* "crude protein" *for* "crude cows protein"
Table 31, page 37 . . .	In the column heading under Holstein Sindhi *read* "Percentage Lactose" *for* "Percentags Lactose"
Table 33, page 41 . . .	In the column heading under village *read* "solids-not-fat" *for* "solds-not-fat"
Table 35, page 44 . . .	In the column under Percentage casein *for* Holstein Sindhi *read* the figures after shifting them by one row upwards
Table 35, page 44 . . .	Last row, *read* "0·07" *for* "0·07*"
Table 37, page 48 . . .	In the column heading *read* "Red Sindhi" *for* "Sindhi"
Table 37, page 48 . . .	In the last row, *read* "—0·06" *for* "0·06"

Table 38, page 49 . . .	In the last row, *read* "0·36*" *for* "0·86*"
Table 39, page 52 . . .	In the column heading 'Specific gravity' under 'village' *read* "1·02705" *for* "1.20705"
Table 39, page 52 . . .	In the column under "Percentage solids-not-fat for Village" *read* "8·813" *for* "8·183"
Table 39, page 52 . . .	In the last row, *read* "—0·29*" *for* "0·29"
Table 39, page 52 . . .	In the last row, *read* "—0·56*" *for* "0·56*"
Table 39, page 52 . . .	In the entries under heading "Village" shift the row reading "/3/1·03022/5·405/8·372/0·7005/2·705/0·1022(3) downwards by one row and shift the remaining eleven rows below this row under the same heading upwards by one row each
Table 40, page 53 . . .	In the last row, *read* "—0·53*" *for* "–053*"
Table 42, page 57 . . .	In the column heading "Percentage Lactose" under village *read* "4·105" *for* "4·015"
Table 49, page 68 . . .	In the column heading "Daily Milk yield oz. for Murrah buffaloes", *read* "88·3" *for* "38·3"
Table 50, page 69 . . .	In the heading *read* "Milk in" *for* "Milking"
Table 54, page 72 . . .	In the column under "Lactose per cent for village Cows", *read* "4·500" *for* "4·520"

BIBLIOGRAPHY

Page 81	Item 6th *read* "Meggitt and Mann (1912) The Composition of the Milk of some Breeds of Indian Cows and Buffaloes and its variation. Part II "*for*" .....1912..... Part II
Page 81, Item 17 . . .	*Read* "Dover" *for* "Dovr"

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PREFACE

Several agencies and individuals made this study possible. The Indian Council of Agricultural Research, New Delhi, made two grants for salaries, chemicals and non-permanent apparatus for the analytical portion and provided the staff and facilities for the statistical portion of the study. The Board of Trustees of the Harvard Yenching Institute of Boston, Massachusetts, U.S.A., provided funds with which the laboratory was equipped with tables, running water, gas lines and permanent apparatus. Sardar Angre Sahib of Gwalior State made a loan to the Allahabad Agricultural Institute in order that it might proceed with the study when other funds had been promised, but not yet received. The Allahabad Agricultural Research Institute provided laboratory space and facilities, the necessary milk for samples, and the staff which supervised the analytical portion of the study arranged and submitted the data for statistical treatment and assisted in preparing the report. Ewin Christian College, Allahabad, loaned the services of a member of the staff of its Department of Chemistry who was head research assistant for two years.

Members of the staff of the Allahabad Agricultural Institute who formulated and directed the project were W. J. Hansen, M.Sc., who first planned the study; Burch H. Schneider, Ph.D., who was responsible for the study when it received the final approval of the Indian Council of Agricultural Research, who organised the study, appointed the research staff, initiated the analytical work and supervised the project for two of the three years when analytical work was in progress; and James N. Warner, M.Sc., who supervised the analytical work during its third year, supervised the preparation of all data to be submitted for statistical treatment and wrote the non-statistical portion of the report.

Those employed for the analytical work were I. D. Dharni, M.Sc., who was head research assistant for two years; B. F. Agarwal, B.Sc. (Agri.), who was head research assistant for one year and research assistant for two years; and S. R. Roy, B.Sc. (Agri.), who was research assistant for one year. The gratitude of the Allahabad Agricultural Institute is extended to Mr Dharni for continuing to help, after his period of employment, in an honorary capacity to check data, search literature for the reports of other studies made in India, and assist in the preparation of the material which constitutes the Historical section.

Other members of the Allahabad Agricultural Institute staff whose assistance deserves mention were Adin P. Brooks, M.Sc., who helped substantially with his advice and suggestions on the methods of chemical analysis and procedure and by keeping all accounts throughout the study; N. R. Joshi, I.D.D., B.A., who willingly helped whenever consulted; and C. O. Das, M.Sc., who was occasionally consulted.

The second part of the report, *viz.*, the Statistical study was completed by the Statistical Branch of the Indian Council of Agricultural Research. P. V. Sukhatme, Ph.D., D.Sc., directed the statistical analysis and interpretation of the results and wrote this part of the report. V. G. Pendharkar, B.Sc., initiated and supervised the calculations and also assisted the senior author of this part in drafting the report. A. N. Sankaran, M.A., is responsible for the major part of the computational work. Other members of the Statistical Branch whose assistance deserve mention are N. P. Natu, M.Sc., N. B. Bagchi, B.Sc., M. K Bose, M.Sc., and S. Raja Ram, B.Sc. (Agri.). The help given by Amar Nath Sharma, Stenographer of the Statistical Section in typing out the report, is also acknowledged.

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PART I
COLLECTION OF DATA

THE COMPOSITION OF MILK

PART I.—COLLECTION OF DATA

1. INTRODUCTION

For generations man has taken a progressively greater interest in the quality of his food. The most primitive human society of the present day follows certain practices in the preparation of food to assure it being of good quality or to make certain that the various aspects of its preparation have been in accordance with the accepted practices. In many countries of the world various standards have been fixed by law to control food quality. These standards fix a basis of quality and or composition for the food products of commerce. The effect such standards may have upon prices that are current within a particular market depends principally upon two things in the market at the time; firstly, the degree of compliance, secondly, the difference between the quality fixed by the new standard and the quality predominating with the new standard which follows and, very extensive agencies for the enforcement of these standards are found in many cases to assure consumers that the foods available in the markets fulfil the requirements set forth. To support such agencies the standards include penalties which may be applied in cases of violation.

Food products are of plant or animal origin. The variations occurring in biological species are distributed over a very wide range. Many food products, therefore, such as milk, vary rather widely in their physical and chemical properties. This variation permits considerable altering of the characteristics of such foods, by the addition of some foreign material or the removal of one or more of its ingredients in whole or in part, without resulting in a departure from the normal range. As the results of such practices are good or bad for society they may be allowed or prohibited.

To avoid interfering with the sale of a genuine product while at the same time preventing the sale of an illegal product, presumptive standards have been established. As the term implies, such standards are based on the presumption that samples which do not meet the specifications indicated are not genuine until the contrary is proved. The fact that a small percentage of genuine products fail to meet their respective standards justifies the presumptive clause.

Presumptive standards may be fixed only after a very extensive study has been made of the food material in question, thereby determining the range of variation of its different characteristics. Within the range of normal variation a value for each important characteristic must be selected which will admit as great a percentage of the samples as possible and yet readily detect altered samples. The very nature of this range necessitates selecting a value which directs suspicion to certain of the low grade or low quality but genuine samples. The fixing of this minimum value is difficult. In the case of samples which are below the standard, the presumptive clause provides for the application of more careful and accurate tests to confirm the genuineness or otherwise of the product.

The food value of the respective constituents of milk in Western countries, for human subjects of those countries, is high. This fact is indicated, in part, by high digestibility coefficients. Studies have not been made as yet which will give the digestibility coefficients for Indian people, of the constituents of milk from the cows and buffaloes of India. No doubt they would also be high. In order, however, to fully comprehend the value of milk as a human food it is necessary to know, in addition to the digestibility coefficients, the content of fat and lactose and the detailed composition of the protein and ash fractions of milk.

The processing of milk in the manufacture of milk products has not been well developed in this country. Any advance in this field of the dairy industry of India must have as its foundation a thorough knowledge of the physical and chemical properties of the raw product.

It is well known that the chemical composition of milk varies as a consequence of numerous factors, such as species and breed of animal, climate, etc. It follows, therefore, that milk from Indian cows will differ from that of cows of other countries and that the milk of the Indian buffalo will differ from both of these. Data available on the detailed composition of milk in India are insufficient to show the nature of these differences. Many of the processes used in the manufacture of the products of milk depend upon its composition. A fuller knowledge of the nature of milk in this country, therefore, will also promote the development of our dairy industry.

2. HISTORICAL

Presumptive standards have existed for milk for some time in many countries. A series of Acts passed in England between 1875 and 1931 have regulated the sale of milk (1). One of the first laws in India governing the control of the sale of milk was the Prevention of Food Adulteration Act of 1919. Acts passed by local bodies, however, date back to the city of Bombay Municipal Act of 1888; the first to deal with adulteration was the Bombay Act II of 1899 (2). The law in the United States (3) indicates that milk shall contain not less than 8 per cent of milk solids-not-fat and

not less than $3\frac{1}{4}$ per cent of milk fat'. The presumptive clause in this law does not apply to milk low in fat but reads as follows with regard to low solids-not-fat: 'failure to satisfy this requirement shall be regarded as merely presumptive evidence of watering and that this evidence shall be confirmed by cryoscope, refractometer, or other approved test for added water.'

The present condition of the milk industry in India, is historically, similar to what other countries have or are experiencing. The practice of adulteration immediately follows the inception of commerce in milk. It continues, as a matter of fact, long after the establishment of presumptive standards and agencies for their enforcement. Several reasons may be given for this, including inadequate agencies of enforcement and the establishment of standards before sufficient knowledge of the milk produced was available. Although laws have existed for years in India, the extent of enforcement is very low. With adulteration as high as 33·3 per cent in 1937 compared to 7·3 to 7·7 per cent in England (4), there is only one sample taken for inspection in approximately 68,000 sales.

Prior to 1919, when the first Food Adulteration Act was passed in India, only three studies of the composition of milk from Indian animals had been made (5, 6, 7 and 8). This paucity of information would indicate that the standards for milk from Indian cows and buffaloes were established without adequate knowledge of such milk. Macmahon, Gupta and Mukerjee (9) say, for example, that their study was made 'with a view to establishing reliable milk standards consequent upon the introduction of the Adulteration of Foods and Drugs Act 1931'. The existing literature contains very few reports of work done on this problem since those of Leather (5), Meggitt and Mann (6, 7) and Leather and Dobs (8).

Leather (5) analysed the milk of individual animals in the herds at Poona, Bombay and Saidapet, Madras. In the former case samples were taken from 'Sind', 'Aden' and 'crossbred' cows; in the latter case the breed is not mentioned.

Determinations were made only of the specific gravity, fat, proteids, ash and lactose with solids-not-fat being calculated by the use of Richmond's formula. He found that the milk of the Indian cow did not differ essentially from cow milk in Europe; and that Vieth's ratio (lactose : proteids : ash) was 13 : 9 : 2.

Meggitt and Mann (6) determined the specific gravity and butterfat percentage and calculated the solid-not-fat, by Richmond's formula, of samples of milk of Gir and 'Sind' cows at the Government Dairy Farm at Poona. They used a lactometer calibrated at 15·5 C. for the specific gravity determinations and the Gerber method for fat. Potassium bichromate was used as a preservative where necessary. The question of butterfat alone is discussed.

These workers report that although the variation in fat percentage of the milk of eight different Gir cows was enormous, there was no very close relationship between this constituent and the yield, except toward the end of the lactation when 'there seems to be a tendency for the milk to get richer'. The yield increased, on an average, until the third month and thereafter declined. The average fat percentage varied from 5·2 in the morning to 6·2 in the evening although the milking interval may have accounted for this.

In the case of 12 "Smd" cows the conclusions were much the same. The composition of the milk of each cow varied only slightly from time to time. There was a tendency, in a few cases, for a slight increase in fat with a decrease in yield. As in the case of milk from Gir cows there were also great differences in the composition of the milk of different 'Sind' cows. The greatest yield likewise occurred in the third month of the lactation. The increase in fat content was more marked as lactation progressed than was true of the Gir. The average fat percentage varied from 6·0 in the morning to 6·3 in the evening, for which the milking interval here also was at least partly responsible.

Leather and Dobbs (8) used the Gerber method of fat determination on milk samples taken from the Montgomery cows at Pusa. They found the average fat content of the milk of these cows to be 4·23 per cent. Differences between the milk from different quarters were insignificant. Calves were allowed, in this case, to suckle one half of the udder while the other half was hand milked. The interval between the two milkings each day was equal, *i.e.*, twelve hours.

Macmahon, Gupta and Mukerjee (9) report a study of a full lactation of each of nine cows and nine buffaloes and of a series of mixed milk samples. All determinations were made by 'common methods of analysis'. The authors state that they did not use the usual formula (Richmond's) for total solids as 'the application of this particular formula is not so reliable in India as has been assumed'. Of the cows six were Hariana, one a 'Sahiwal', one a crossed 'Sahiwal' and Hariana and one crossed Ayrshire and Hariana. These writers state that there is probably a rough relationship between fat percentage and yield. They base this statement on the fact that whereas the yield is higher in the morning and in the early part of the lactation than in the evening and later part of the lactation, the fat percentage is lower. The solids-not-fat, on the other hand, was very constant. The milking interval is not indicated. Vieth's ratio of 13 : 9 : 2 'appears to be inapplicable to milk of the United Provinces'

although, as already stated (5), it was used earlier at Poona. These authors report a Vieth's ratio of 13: 9·6: 2 for morning milk and 13: 9·8: 2 for evening milk, showing slightly higher proteids percentage than in Europe or at Poona.

Analysis of 83 samples of cow milk from a 'local dairy' showed a specific gravity of 1·0302, fat 5·48 per cent, solids-not-fat 8·78 per cent and ash 0·700 per cent.

Smith (10), reports that the Scindi cattle are distributed from Mesopotamia to Borneo. He gives the production records of cows of this breed in different places to confirm his statement that 'Although the Scindi breed provides in its own country a very good example of dual purpose qualities, it is as a milch cow that it is known throughout the East.' Daily determinations for a period of 14 days are reported on eight 'Scindi' cows at the Imperial Institute of Animal Husbandry and Dairying, Bangalore. The average for morning and evening milk respectively are: specific gravity 1·0301 and 1·0299, fat 4·21 and 5·10 and total solids 12·80 and 13·84; the averages for all samples were: specific gravity 1·0301, fat 4·65 and total solids 13·32. The methods of determination are not given.

Whereas Leather (5) and Meggitt and Mann (6 and 7) used Richmond's formula for calculating the solids-not-fat of samples they studied and Macmahon, Gupta and Mukerjee (9) concluded that the formula was not applicable in tropical climates: it was not until 1933 that a modification of this formula was made (11). Hawley states that Richmond's formulae are useful for temperate climates but not in the tropics. This is accounted for by the fact that 'the coefficient of expansion of milk of low gravity is very different according to whether the milk is watered or contains an excess of fat' he says. The formula which he suggests, is as follows:

$$\text{S. N. F.} = 0{\cdot}2872\frac{G}{D} + 0{\cdot}328\ F,$$

where S. N. F. is the percentage of solids-not-fat, F is the percentage of fat, D is the specific gravity at 85°F./60°F. glass in air and G is 1000D-1000. According to the author this formula has been tried on many hundreds of samples and works as well for the milk of the 'Madras' cow as for that of the buffalo. If, however, as stated, the variation in low specific gravity milk is greatly influenced by the fat content, then the fat content of buffalo milk might obviate the applicability of such a formula to milk of both cows and buffaloes.

Smith and Littlewood (12) give limited data on the fat content of the milk from six Ongole or Nellore cows owned by the Madras Agricultural Department. They indicate an average of 5·03 per cent fat; 4·70 per cent for morning milk and 5·36 per cent for evening milk. The average for the milk of eleven Ongole cows at the Agriculture College Dairy, Coimbatore, is also given as 4·50. Neither the method of analysis nor the milking interval is given.

Kothavalla (13) reports on the specific gravity and the percentages of fat and solids-not-fat of milk from Kankrej cows at two centres. At the Bombay Government Cattle Farm, Surat, the figures for morning and evening milk respectively were: specific gravity 1·0292 and 1·0297, fat 4·10 and 4·74 and solids-not-fat 8·304 and 8·059; at the Bombay Government Cattle Farm, Chharodi, they were: specific gravity 1·0285 and 1·0285, fat 3·83 and 4·08 and solids-not-fat 8·094 and 8·169 respectively. The averages of all samples reported at the first centre are 1·0295 specific gravity, 4·42 fat and 8·181 solids-not-fat; at the second centre 1·0285 specific gravity, 3·95 fat and 8·131 solids-not-fat. The milking interval and methods of analysis are not given.

Kothavalla and Kartha (14) report an average fat percentage of 4·595 for the milk of Hariana and 4·553 for Tharparker cows at Karnal; little relationship between fat percentage and level of production was noted in either case. The rates per month of increase in fat in the milk as lactation advanced were 0·079 per cent for Hariana and 0·062 per cent for Tharparker cows.

Leather (5) observed, with regard to buffalo milk, 1. that the butter fat was high, 7 to 8 per cent being common, 2. that proteids were higher than in cow's milk and 3. that the Veith's ratio was 10 : 12 : 2. The breed and the methods of analysis are not given.

Meggitt and Mann (7) studied the milk of 18 Surti, 1 Jaffarbadi, 2 Delhi and 2 Deccani buffaloes. Using the Gerber method for fat, a lactometer corrected to 15·5°C. for specific gravity and Richmond's formula for solids-not-fat determinations, these writers found a Vieth's ratio for mixed buffalo milk of 6 : 5·2 : 0·98 which, the ysay, is very close to that for the Egyptian buffalo as reported by Richmond. The fat content of the mixed milk was 7·06 per cent in morning and 7·92 per cent in evening. Only slight seasonal variations are indicated, except during the monsoon when there was a distinct drop in the fat. Greater variations, they note, occur in the fat content of the milk of a buffalo than of a cow.

The fat content of the morning and evening milk respectively of the Surti animals is 8·3 and 8·5 per cent; the total solids was 18·7 per cent and 18·8 per cent respectively. There was only slight evidence of an increase in the fat content with a decrease in production.

Smith (15) gives the analysis of 658 samples of the milk of 'Murrah' buffaloes at Karnal, Punjab,

Bangalore and Mysore. His data average 7·12 per cent fat with a specific gravity of 1·0291. Again the methods of analysis are not given.

Shah (16) reports briefly on the composition of the colostrum, taken immediately after calving, of three Montgomery cows. His findings are: specific gravity 1·0573, total solids 22·55 per cent, fat 4·6 per cent, milk sugar 3·30 per cent, total proteins 13·22 per cent, casein 4·56 per cent, albumin and globulin 8·70 per cent, ash 1·23 per cent and acidity 0·134 per cent. He also does not give the methods of determination of these constituents.

Sivasubramanian and Dover (17) report the following composition, immediately after calving, of the colostrum of three Sindhi cows: specific gravity 1·063, total solids 18·2 per cent, fat 2·0 per cent, lactose 2·2 per cent, total protein 12·8 per cent, casein 4·0 per cent, albumin 2·6 per cent, globulin 6·2 per cent and ash 1·0 per cent. The composition immediately after calving, of the colostrum of three Murrah buffaloes was: specific gravity 1·074, total solids 29·9 per cent, fat 3·9 per cent, lactose 2·2 per cent, total protein 21·4 per cent, casein 6·8 per cent, albumin 3·8 per cent, globulin 10·8 per cent and ash 1·1 per cent. Details of the standard methods used in these analyses are given by the authors.

Macmahon and Srivastava (18) give the mean freezing point depression, using the Hortvet apparatus and following the A.O.A.C. procedure, of cow and buffalo milk. Samples were taken at the Military Dairy Farm, Lucknow, and tested before the development of undue acidity. They found a freezing point depression of 0·551°C. for 134 samples of cow milk and 0·561°C. for 137 samples of buffalo milk; the average value for 42 individual cows was 0·552°C. and for 33 individual buffaloes 0·562°C.

3. EXPERIMENTAL

Animals

The experimental animals were selected from the herds of the Allahabad Agricultural Institute and three village centres where the Department of Animal Husbandry and Dairying maintained milking stations from which to obtain an additional supply of milk. The milking animals maintained by the Institute were: purebred Red Sindhi cows and Murrah buffaloes; crossbred Holstein-Sindhi and Jersey-Sindhi cows; and grade Red Sindhi, Kankrej, Holstein, Jersey, Guernsey and Brown Swiss cows. Village animals were desi cows and buffaloes of the types typical in the Allahabad District of the United Provinces. The age of each animal was not known. Where this factor was known, however, it varied from three to sixteen years. Unquestionably this range includes the unknown ages. It so happened that all Holstein Sindhi animals on which individual tests were run in this study were sired by the same Holstein-Friesian bull.

Table 1 indicates the number of animals in each group, the number of lactations completed, the causes for incomplete lactations, the total number of lactations studied and the numbers of animals of each group for which tests cover two or three lactations.

TABLE 1

Breed	No. of animals	Number of lactations studied							Duplicate lactation	Triplicate on the same animal.
		Completed	Not completed					Total		
			died	sold	loaned	Removed from herd	Tests discontinued			
Red Sindhi	29	29	1	0	1	0	3	34	3	1
Holstein-Sindhi	6	8	0	0	0	0	0	8	2	0
Murrah	15	17	0	1	0	0	0	18	1	1
Village cows	12	11	0	0	0	1	0	12	0	0
Village buffaloes	28	26	0	2	0	2	2	32	4	0
TOTAL	90	91	1	3	1	3	5	104	10	2

Some animals were loaned by the institute to village owners during the study. Of these, Red Sindhi cows 133, 294 and 304 and Murrah buffalo 80 (54) started lactations at the Institute which were completed in a village; Murrah buffalo 80 (54) completed a second lactation in a village. Red Sindhi cow 198 and Murrah buffalo 39 were tested throughout one lactation at the Institute and two additional ones in a village. Red Sindhi cow 4 was tested during a full lactation in a village.

The study was originally approved for a period of two years. Near the end of this time it was extended for one year. Since it was desired that tests cover complete lactations as far as possible

the animals were selected at parturition from the beginning of both the original and the extended periods. This continued until such time as it was thought further lactations might not be completed before the termination of the period in question. This method necessarily reduced the number of lactations on which tests might have been made had selection of animals not been interrupted as it was at the end of the first period.

Feed and Care. All animals under test were subjected to routine care and management either at the Institute or in the villages. Conditions and practices routine in one place were different, however, from those in the other. The Animal Husbandry and Dairying Department kept its animals in the milking berns only during the cold winter nights and the hot summer days. Otherwise they were turned loose in open paddocks. Those cows giving over ten pounds of milk daily were milked three times; buffaloes and the lower producing cows were milked twice. Village animals were kept tied under trees at all times and were milked only twice daily.

Feeding practices followed at the Institute were based on the Morrison feeding standard (19), using available information concerning the composition and digestibility of Indian feeds. Roughages consisted of green napier or guinea grass; silage made of napier grass, *bajra* or *jwar*; and occasional small amounts of green weeds or wheat or barley *bhusa*. Green roughages and silage were fed at the rate of 6 lb. daily for each 100 lb. bodyweight. When fed, 1 lb. of *bhusa* replaced $2\frac{1}{2}$ lb. of green roughages.

During the greater part of the study, the concentrate mixture contained wheat bran 50 parts, mustard cake 30 parts, linseed cake 10 parts, crushed gram 10 parts and mineral mixture 3 parts. The mineral mixture contained bone meal, common salt, air slaked lime and potassium iodide. These were two occasions when this concentrate mixture was slightly changed; from February 15 to May 15, 1937 the linseed cake was replaced by additional mustard cake, and during February 1938 the crushed gram was replaced by *arhar chuni*.

Village animals received *jwar* or *bajra* stover, *dub* grass, or barley or wheat *bhusa* and occasional small amounts of pumpkin leaves, potato vines or green weeds as roughages. A few village *gwalas* purchased the regular concentrate mixture from the Institute. The majority of them, however, fed mustard cake, *arhar* husk and *arhar chuni* in varying combinations and amounts, with common salt as a supplement.

Health. The tests on only 12 of the 90 experimental animals were disturbed because of illness. Of the Institute animals, Red Sindhi cows 444, 301 and 42 and Holstein-Sindhi cow 93 suffered from udder congestion as a result of which 301 milked from only three quarters thereafter; Red Sindhi cow 299 died of bronchopneumonia; and Red Sindhi cows 454 and 446 suffered from slight attacks of foot and mouth disease from which they quickly recovered. Of the village animals the cow Bundel and buffaloes Dulariya, Elizabeth and Sulochna dried off prematurely, the latter after the death of her calf; and buffalo Dulariya suffered briefly from slight indigestion.

4. SAMPLES

Individual

Twenty-four hour samples were taken once during the first three days after parturition and fortnightly thereafter. Portions of each milking during the sampling day were taken by means of a device, made by the Engineering Department of the Institute, similar to that described by Overman, Sanmann and Wright (20). It consisted of two vertical cylinders of the same length; a large one with a capacity of approximately two Imperial gallons and a small one having exactly one-eighteenth the capacity of the larger. They were connected at the bottom by a two-way brass cock. The milk produced at each milking was carefully mixed by pouring from one pail to another a few times. For sampling the two cylinders were connected by means of the cock, the fresh milk was poured into the larger from which it flowed into the smaller to a common level. A sample bottle was then placed under the cock and it was turned to close off the small cylinder from the larger. At the same time the contents of the small cylinder drained into the sample bottle, giving an aliquote of the original quantity. Samples were made up of such portions of each milking in a 24 hour period.

Ice was used in an insulated box to hold the first portions of a sample until the latter portions were added. Sampling was carried out so that the sample was completed with the early morning milking. As the samples arrived in the laboratory, they were first warmed up to 38°C. for mixing and then cooled to 20°C. Each sample was analysed on the day it was received. It was again carefully mixed just before analysis.

Herd

Samples were taken of the milk of three groups of animals at the Institute and one group in each of the three village milking stations. The groups at the Institute consisted of 1. purebred Red-Sindhi cows, 2. purebred Murrah buffaloes and 3. purebred, crossbred, and grade cows and purebred buffaloes. That in each village milking station consisted of all desi cows and buffaloes milking at the time. 'Sindhi Herd' and 'Murrah Herd' samples were obtained from group 1 and 2 at the Institute. 'Mixed Herd' samples were obtained from group 3 at the Institute and from each of the three village groups. With the exception of that of Ganeshganj, the

total milk produced by one group of animals at one milking was put into a can where it was carefully mixed by stirring. An aliquote portion of 10 c.c. for each pound was taken in a graduated cylinder. A cream separator was maintained at the Ganeshganj centre with which all milk was separated: the cream only being returned to the Institute. Portions of each milking at this centre, therefore, were obtained from the cans into which the milk was put before separating.

Genuine

These were made up of portions of each milking obtained as stated above, and handled thereafter in the manner described for the individual samples.

Toned

A part of a genuine herd sample was separated in a 'Clock, No. 10' table separator, a Swedish machine obtained from The Dairy Supply Co., Ltd., London. The skim milk so obtained was tested for butterfat and then used to standardize or tone other parts of the sample from which it was taken. Skim milk from one sample was never used to tone a part of a different sample.

Existing standards in India regarding the minimum fat content of market milk are usually 3·5 per cent for cow's and 5·0 per cent for buffalo's milk; mixed milk standards are either 3·5 or 5·0 per cent (2). For purposes, therefore, of getting some information with respect to the effect of toning milk from its original composition to these minima, samples of cow's milk were toned to 3·5 per cent fat and samples of buffaloes milk were toned to 5·0 per cent and 3·5 per cent fat.

Adulterated samples

Ordinary distilled water was used for adulterating samples in this study.

5. ANALYTICAL METHODS

Analytical methods followed are for the most part the '*Methods of Analysis of the Association of Official Agricultural Chemists*' (21), referred to below as A. O. A. C. Other references which were used are indicated. The first determination to be made in each case was the specific gravity. Portions of the sample required for subsequent determinations were taken immediately thereafter before any change had taken place in the temperature.

Specific gravity

The specific gravity was determined by the lactometer method, two lactometers being used. A Soxhlet type lactometer made by Baird and Tatlock, Ltd., London, was used on the first 220 samples. This was graduated from 1·020 to 1·042 over a scale $3\frac{3}{4}$ inches long. Graduations were at intervals of 0·001 with finer estimations possible. The instrument was specially calibrated for tropical countries to read correctly at 85°F., at which temperature the readings were made. As soon, however, as a lactometer which was corrected to 15°C. became available, it was used since most of the previous workers had used this type of lactometer.

The second lactometer was used on all other samples. This instrument, of German make, was accompanied by a certificate of accuracy from the German Physical Technical Institute. It was graduated from 1·020 to 1·040 over a scale $2\frac{1}{2}$ inches long. Graduations were at intervals of 0·001 with finer estimations facilitated by a black background on the scale. The lactometer was calibrated to read correctly at 15°C., and the samples were cooled to this temperature before the readings were made.

In order to compare the two instruments, readings were made with each on a large number of samples at their respective temperatures. They were found to agree within their reading errors.

Total Solids

Five c.c. of milk were weighed into a flat-bottomed aluminium dish containing dry sand, evaporated on a water bath and then dried in an electric oven at 105°C. for three hours, cooled and reweighed (A. O. A. C. XXII, 8).

Moisture

The moisture was determined by difference between the total solids and 100.

Fat

The standard gerber method was followed, using 10 c.c. sulphuric acid, 11 c.c. milk and 1 c.c. amyl alcohol. The acid and alcohol were measured by automatic devices. The centrifuge had a diameter of 18 inches and a capacity of sixteen tests and operated at about 1100 R. P. M. The butyrometers were carefully selected from a large stock, any which gave discrepancies being discarded. Those graduated to 9 per cent were used for buffalo milk, while 7 per cent butyrometers were used in most cases for cow milk. Tests were always made in duplicate, and if these did not check closely they were repeated at once.

Solids-not-fat

The solids-not-fat were determined by difference between the total solids and the fat.

Lactose

During part of the first year lactose was determined by Gohr's microchemical method (22).

After the first few months lactose was determined by an official A. O. A. C. method. Twenty-five c. c. of the milk sample was diluted in a volumetric flask. Proteins, fat, and other reducing substances were removed with copper hydroxide, the solution made up to volume and filtered. An aliquot of the filtrate was treated with Fehling's solutions and the amount of copper in the precipitated cuprous oxide determined by the iodimetric method. From appropriate tables the percentage of equivalent hydrous lactose, $C_{12}H_{22}O_{11}\cdot H_2O$, was calculated. (A. O. A. C. XXII, 18.)

Crude protein

A modified Kjeldhal method was used to determine the total nitrogen in a 5 c.c. sample of the milk taken immediately after the determination of the specific gravity. The sample was digested in an 800 c.c. Kjeldhal flask with concentrated sulphuric acid and anhydrous sodium sulphate, using $CuSO_4$ and selenium as catalysts. The percentage of total nitrogen (which includes some non-protein nitrogen) multiplied by 6·38 gives the percentage of crude protein. (A. O. A. C. XXII, 10.)

True protein

This was determined by precipitation of the true proteins from a sample of the milk with 20 per cent trichloracetic acid, filtering, and determining nitrogen in the precipitate thus obtained by the modified Kjeldhal method. The nitrogen value so obtained, multiplied by 6·38 gives the percentage of true protein.

Non-protein nitrogen

The difference between the crude protein nitrogen and the true protein nitrogen was considered to be the non-protein nitrogen.

Casein

A 10 c.c. sample of the milk was diluted with water and the casein precipitated with 10 per cent acetic acid. The nitrogen content of this precipitate was determined by the modified Kjeldhal method. This value multiplied by 6·38 gave the casein. (A. O. A. C. XXII, 11.)

Albumin and minor proteins

This was determined by difference between the true protein and the casein. It includes in addition to albumin, other minor proteins present in the milk.

Ash

To 20 c.c. of the milk sample taken immediately after the determination of the specific gravity in a weighed dish, 6 c.c. of HNO_3 was added, the mixture was dried over a water bath, charred over a low flame, and ignited in an electric muffle furnace at 580°—600°C. until free from carbon, cooled in a desiccator and reweighed. (A. O. A. C. XXII, 9.)

Analysis of ash

The ignited residues obtained from the duplicate determinations of the ash obtained as outlined above were dissolved in HCl, the solutions combined in a volumetric flask, and made up to volume. Aliquots of this solution were used to determine P_2O_5, CaO, MgO, K_2O and Na_2O by standard methods.

(*a*) *Calcium oxide.* A suitable aliquot of the ash solution was treated with $FeCl_3$ and NH_4OH to remove phosphates, and calcium precipitated from this filtrate with oxalic acid, first in slightly acid solution to prevent coprecipitation of magnesium, and finally in alkaline solution. The percentage of CaO was determined volumetrically from the precipitated oxalate with standard $KMnO_4$ (23).

(*b*) *Magnesium oxide.* On the few occasions when this determination was made the method used was to precipitate the magnesium as a phosphate from the filtrate from the calcium determination, filter, ignite, weigh as $Mg_2P_2O_7$ and calculate to MgO. (A. O. A. C., 19, method I.)

(*c*) *Potassium and sodium oxides.* A suitable aliquot of the ash solution was freed from phosphate, sulphate, calcium, magnesium, and ammonium salts and all other elements except chlorides of sodium and potassium by appropriate proceedures. When it was desired to determine sodium, the properly purified mixed chloride solutions were dried and weighed. When sodium was not to be determined this step was omitted. The chlorides were then dissolved and the potassium precipitated as perchlorate in presence of alcohol, and later filtered, dried, weighed and the per cent K_2O calculated. From this value, and the weight of sodium and potassium chloride previously obtained, the per cent Na_2O was calculated.

The solutions were purified according to A. O. A. C. II, 47, followed by the perchlorate method outlined by Knowles and Watkin (24).

(*d*) *Phosphorus pentoxide.* A suitable aliquot of the ash solution was treated with ammonium molybdate to separate the phosphate and the per cent of P_2O_5 determined volumetrically by suitable standard alkali and acid solutions (25).

(*e*) *Chlorine.* This was the only mineral constituent not determined on the ignited residue from the ash. It was, instead, determined by the wet oxidation of a 10 c.c. sample of the milk with hot concentrated HNO_3 and saturated $KMnO_4$ in the presence of an excess of standard $AgNO_3$. When organic matter had been destroyed the solution was filtered and the excess of silver nitrate titrated with KCNS using ferric alum indicator, and the percent chlorine calculated (26, 27).

Freezing point

The Hortvet Cryoscope was used, following closely the method of A. O. A. C., XXII, 25 and 27.

Two methods of standardization of the thermometers were used :

Distilled water was redistilled after adding alkaline $KMnO_4$ in a 500 c.c. distilling flask connected to a Leibig condenser. The condensate was received directly in Jena glass bottle. The whole apparatus was thoroughly cleaned before use. The first three 25 c.c. portions of distillate were used to rinse out the receiving bottle and then discarded. The freezing point of this redistilled water was carefully determined, and then checked periodically as a check on the correction factor for the thermometer.

The second method involved the use of standard sucrose solutions. The procedure outlined in A. O. A. C. XXII, 26 was followed.

Two standard thermometers were used due to the breakage of the first. The first, No. 3242088 was supplied with the Hortvet Cryoscope by Sutherland Thomson and Co., Ltd., London. The bulb was approximately 5 cm. long and 8 m.m. wide. The thermometer was graduated from −2·00°C. to +1·00°C. over a scale 21 cm. long. Graduations were made at 0·01° C. intervals with easy estimation to 0·002° C. The overall length of the instrument was 57 cm. The upper end of the capillary was provided with an expansion bulb. The second, No. 50203, was supplied by Baird and Tatlock, Ltd., London. The bulb was approximately 6 cm. long and 10 m.m. wide. The distance to the lowest graduation from the bottom of the bulb was 25·5 cm. The thermometer was graduated from −2·00°C. to +1·00°C. over a scale 30·6 cm. long. Graduations were made at 0·01°C. intervals with easy estimation to 0·001°C. The overall length of the instrument was 60 cm. The upper end of the capillary was provided with an expansion bulb. No certificate of standardization accompanied either thermometer, but both were carefully checked by the methods mentioned and correction factors established. All determinations in this study were corrected by using these factors.

6. NUMBERS OF DETERMINATION

The total number of samples analysed was 2,092. The number of determination was 22,464. Of these 17,507 were made by chemical or physical means involving 28,710 analyses ; 4,957 were determined by difference, as indicated above.

The following determinations involved duplicate analyses of which the average was reported : total solids, fat, lactose, crude protein, true protein, casein and ash. Of the remaining determinations specific gravity, calcium oxide, magnesium oxide, potassium oxide, sodium oxide, phosphorous pentoxide and chlorine involved single analyses ; moisture solids-not-fat, non-protein nitrogen and albumin and minor proteins were determined by difference involving the results of single analyses and/or the means of duplicate analyses ; freezing point involved duplicate observations on the same portion of a milk sample which was allowed to thaw between observations. Table 2 gives the number of determinations, the number of analyses and the number of those determinations arrived at by difference.

TABLE 2

Constituent	Determinations	Chemical or physical analyses	Determinations by difference
Specific gravity	2,092	2,092	..
Total solids	2,090	4,180	..
Moisture	2,090	..	2,090
Fat	2,092	4,184	..
Solids not-fat	2,088	..	2,088
Lactose	2,070	4,140	..
Crude protein	2,065	4,130	..
True protein	396	792	..
Non-protein nitrogen	391	..	391
Casein	405	810	..
Albumin and minor proteins	388	..	388
Ash	2,085	4,170	..
Calcium oxide	1,092	1,092	..
Magnesium oxide	30	30	..
Potassium oxide	6	6	..
Sodium oxide	6	6	..
Phosphorous pentoxide	1,117	1,117	..
Chlorine	1,398	1,398	..
Freezing point	563	563	..
TOTAL	22,464	28,710	4,957

PART II

STATISTICAL STUDY

THE COMPOSITION OF MILK

PART II.—STATISTICAL STUDY

1. INTRODUCTION

THE object of Part II of the Report is to discuss the results of statistical analysis of the data collected under the Milk Composition Scheme of the Council at Allahabad. This is done under seven different sections as follows :

(1) Variations in the percentage of the constituents and other characters of milk of individual cows and buffaloes.

(2) Variations in the composition of mixed and toned milk.

(3) Comparison of the average composition of milk derived from the Allahabad data with that obtained by other workers in India and abroad.

(4) Milk standards.

(5) Correlations between the various characters of milk.

(6) Influence of the period of lactation and of season on the yield of milk, its specific gravity and its main constituents.

(7) Prediction of the percentage of solids-not-fat from the observed values of specific gravity and the percentage of fat.

All, excepting a small fraction of the samples of milk collected under the scheme, have been utilised for the statistical analysis. The following are the particulars of the samples omitted :

(*a*) Samples of milk of the Red Sindhi cow, Phulwati, which suffered from udder inflammation in the third month of her lactation and gave milk which was found to be abnormally low in specific gravity and butter fat content.

(*b*) Samples of one village cow about which no information regarding the date of calving etc., was available.

(*c*) All samples during the colestrum period.

2. VARIATIONS IN THE PERCENTAGES OF THE CONSTITUENTS AND OTHER CHARACTERS OF MILK OF INDIVIDUAL COWS AND BUFFALOES

Specific gravity (Table 1)

The frequency distributions of the specific gravity in samples of milk of individual cows and buffaloes shown in Table 1 are all asymmetrical, with longer tails on the lower side of the mean values. In statistical terminology we would say that the distributions are negatively skew. The table shows that the values around which the distributions are centred are different in different groups of cows and buffaloes. The mean values of specific gravity given at the end of the table show that the buffaloes' milk is significantly heavier than the cows' milk. That is to say, the difference between the mean values of the two groups is more than can be explained in terms of the variation from sample to sample of the same group. The milk of village buffaloes is heavier than the milk of Murrah. Among the cows the milk of village cows is the heaviest with Red Sindhis following it.

The range of variation goes from 1·0190 to 1·0370 in samples of milk of village cows against the corresponding values of 1·0210 and 1·0390 for buffaloes' milk. The range in the case of the Red Sindhi and Holstein Sindhi groups is even smaller. Relative to the mean the variation as measured by the standard deviation is only of the order of 0·2 per cent. It will be found later that the specific gravity is the least variable of all characters of milk.

Except in Bengal, United Provinces, and Assam no legal standards for specific gravity exist in India. According to the law the specific gravity should be between 1·028 and 1·030 in the United Provinces and Bengal and not less than 1·028 in Assam. There is no difference in the standards for milk of cows and of buffaloes. It will be seen from the table that a large proportion of genuine samples of milk of individual cows and buffaloes fails to pass the legal test, but it will be shown later that this proportion diminishes with the increase in the size of the herd and is almost negligible when the herd is of six or more animals.

Percentage butter-fat (Table 2)

The frequency distributions of the percentage butter-fat in samples of milk of individual cows and buffaloes are shown in Table 2. It will be seen that all the distributions are asymmetrical with a longer tail on the upper side of the mean value. The mean butter-fat content is distinctly different for cows' and for buffaloes' milk, the milk of the latter being very much richer in the fat content. It will be seen that whereas the village buffaloes' milk

TABLE 1

Frequency distribution of Specific Gravity in fortnightly samples of milk of individual cows and buffaloes

Specific Gravity	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+1·0180	..	..	..	..	1	..	1
+1·0190	..	..	1	1	1	..	1
+1·0200	..	1	..	1	1	..	1
+1·0210	1	..	2	3	1	1	2
+1·0220	1	..	2	3	3	3	6
+1·0230	1	..	1	2	..	3	3
+1·0240	3	..	1	4	1	1	2
+1·0250	11	2	2	15	5	4	9
+1·0260	9	7	3	19	4	2	6
+1·0270	19	11	7	37	9	14	23
+1·0280	32	27	12	71	20	26	46
+1·0290	66	63	24	153	29	62	91
+1·0300	131	44	27	202	45	89	134
+1·0310	167	14	33	214	72	80	152
+1·0320	100	2	30	132	59	87	146
+1·0330	37	..	25	62	24	55	79
+1·0340	7	..	9	16	21	45	66
+1·0350	1	..	6	7	7	9	16
+1·0360	..	..	1	1	3	9	12
+1·0370	..	..	..	.	1	3	4
+1·0380	..	..	..	..	1	3	4
Total	586	171	186	943	308	496	804
Mean value	1·03088	1·02950	1·03104	1·03066	1·03122	1·03156	1·03143
Standard Deviation	0·00188	0·00147	0·00274	0·00209	0·00266	0·00242	0·00237
Coefficient of Variation (per cent)	0·18	0·10	0·27	0·20	0·26	0·23	0·23

contains a mean butter-fat content of 7·6, the corresponding value for cows' milk is only 5·6. There is also a considerable variation in the butter-fat content of milk of different groups of cows and of buffaloes. The milk of Holstein Sindhi and Red Sindhi cows is poorer in butter-fat content than the milk of village cows. A similar result is noticed among buffaloes, the butter-fat content of the milk of Murrah buffaloes being less than that of the milk of village buffaloes. The frequency distributions show that there is a considerable variation in the butter-fat content of different samples. Thus the range of variation for Red Sindhi cows is from 2·0 to 9·2 per cent. The range for other groups of cows is equally large. The range of variation for buffaloes' milk is even larger, going from 3·2 to 12·8 per cent in the Murrahs and 4·0 to 14·0 per cent in village buffaloes. The variation relative to the mean is, however, about the same in both cows and buffaloes, being of the order of 20 per cent, a figure which agrees well with the value given by Tocher and other workers.

The existing standard in most provinces in India or the butter-fat content of cows' milk is 3·5 and for buffaloes' milk varies from 5·0 to 6·0. The frequency distributions show that 4·3 per cent of the samples of milk of individual cows of the Red Sindhi group have a butter-fat content less than what is required by the legal standard; in other words 43 out of every 1,000 genuine samples of milk of cows of the Red Sindhi group fail to pass the legal test. In the Holstein Sindhi group, the percentage failure is even greater, being 11·7. In village cows only about 4·4 per cent of samples have a butter-fat content less than 3·5. In buffaloes, the percentage samples giving less than 5 per cent of butter-fat content are only 3·1 in the Murrah group and 3·6 in village buffaloes; but the percentage of samples having less than 6 per cent of butter-fat content are larger, being 16·2 in the Murrah group and 15·7 in the village buffaloes. In other words if the milk of individual animals were put and sold in the market as many as 16 out of every 100 genuine sellers might be unjustly punished under the law. A large proportion of milk sold in the market is, however, not of individual animals but is a pooled product of a herd of several animals and as we shall see later the chance of such product failing to pass the legal test is almost negligible.

TABLE 2

Frequency distribution of Percentage Butter-Fat in fortnightly samples of milk of individual cows and buffaloes

Percentage Butter-Fat	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+2·00	1	..	..	1	..	..	..
+2·40	4	1	..	5	..	..	..
+2·80	6	4	3	13	..	..	..
+3·20	19	20	7	46	1	..	1
+3·60	63	35	7	105	2	..	2
+4·00	85	45	15	145	3	4	7
+4·40	111	18	22	151	2	5	7
+4·80	95	19	21	135	3	18	21
+5·20	79	13	19	111	13	20	33
+5·60	53	6	21	80	26	31	57
+6·00	28	2	17	47	41	35	76
+6·40	16	3	20	39	48	31	79
+6·80	12	4	15	31	37	52	89
+7·20	9	1	12	22	33	68	101
+7·60	1	..	3	4	35	43	78
+8·00	2	..	2	4	16	57	73
+8·40	..	..	1	1	11	41	52
+8·80	2	..	..	2	15	30	45
+9·20	..	..	1	1	7	9	16
+9·60	..	..	..	..	4	8	12
+10·00	..	..	..	..	3	17	20
+10·40	..	..	..	..	3	7	10
+10·80	..	..	..	..	1	5	6
+11·20	..	..	..	..	..	1	1
+11·60	..	..	..	..	1	7	8
+12·00	..	..	..	..	2	5	7
+12·40	..	..	..	..	1	1	2
+12·80	..	..	..	..	..	..	..
+13·20	..	..	..	..	..	..	..
+13·60	..	..	..	..	..	1	1
Total	586	171	186	943	308	496	804
Mean value	4·925	4·420	5·607	4·968	7·161	7·624	7·446
Standard Deviation	0·970	0·888	1·234	1·026	1·375	1·598	1·532
Coefficient of Variation (per cent)	19·7	20·1	20·8	20·7	19·2	21·0	20·6

Percentage solids-not-fat (Table 3)

Unlike the percentage butter fat, the frequency distributions of the percentage solids-not-fat in samples of milk of cows and of buffaloes may be regarded as symmetrically disposed round the mean value. The table shows that there is more solids-not-fat in the buffaloes' milk than in the cows' milk. There appears to be in fact a positive correlation between the butter-fat content of milk of a group and the solids-not-fat content of milk of the group. For, the Holstein Sindhi group which gives the least mean value for the butter-fat content also gives the least mean value for the solids-not-fat content; and the village cows' milk which is the richest in the butter-fat content is also the richest among the cows' milk in the solids-not-fat content. In buffaloes, too, the village buffaloes' milk which is richer in the butter fat content than the milk of Murrahs' shows a higher content of the solids-not fat. The actual mean values are 9·386 per cent for village buffaloes against the corresponding value of 8·702 for village cows; 9·215 for Murrah milk; and 8·079 and 8·497 for Holstein Sindhi and Red Sindhi cows' milk. The range of variation is smaller for the percentage solids-not-fat than for the percentage butter-fat. The range for the village cows' milk is from 5·8 to 10·6, for Red Sindhi cows' milk from 5·6 to 0·8 and for Holstein Sindhi cows' milk from 6·6 to 10·0. The variation relative to the mean is, however, about thrice as small as in the case of the percentage butter fat, the value for the coefficient of variation being 8·1 per cent for the milk of village cows. 6·3 per cent for Red Sindhi cows, 5·3 per cent for Holstein Sindhi cows, 6·7 per cent for village buffaloes and 7·2 per cent for Murrah buffaloes.

Like butter fat there also exists a legal standard for minimum solids-not-fat. For cows' milk it is 8·5 per cent in most provinces and for buffaloes' milk it is 9 per cent except in the Central Provinces where it is 8·5 per cent. It will be seen that the minimum standard for cows' milk is even higher than the mean value of the percentage of solids-not-fat in Red Sindhi and Holstein Sindhi groups. This shows that more than half the number of genuine samples of milk of Red Sindhi and Holstein Sindhi cows fails to pass the legal test. This is doubtless too hard for sellers of milk of cows of these groups,

but what is even worse is that even if milk sold in the market were of a herd of more than one cow there will be no diminution in the proportion of genuine samples failing to pass the legal test as long as the standard remains higher than the mean value itself. In village cows the proportion of genuine samples of milk of individual cows failing to pass the legal test is 0·34; in Murrah and village buffaloes the proportions are 0·28 and 0·19 respectively; but as we shall see later these proportions decrease with the increase in the size of the herd and the chance of a genuine product failing to pass the legal test becomes small.

TABLE 3

Frequency distribution of Percentage Solids-not-fat in fortnightly samples of milk of individual cows and buffaloes

Percentage Solids-not-fat	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+5·40	..	..	..	..	1	..	1
+5·60	1	..	..	1	2	..	2
+5·80	1	..	1	2	..	..	..
+6·00	1	..	..	1	..	1	1
+6·20	..	..	..	..	1	..	1
+6·40	2	..	3	5	..	2	2
+6·60	1	1	1	3	1	..	1
+6·80	1	1	1	3	1	..	1
+7·00	2	1	..	3	..	2	2
+7·20	9	3	1	13	1	2	3
+7·40	10	7	3	20	2	..	2
+7·60	14	22	7	43	1	1	2
+7·80	36	40	8	84	3	4	7
+8·00	52	44	9	105	2	4	6
+8·20	104	28	16	148	5	5	10
+8·40	106	10	28	144	11	13	24
+8·60	95	8	25	128	17	22	39
+8·80	73	1	23	97	39	39	78
+9·00	47	1	13	61	52	73	125
+9·20	14	1	22	37	55	88	143
+9·40	12	..	11	23	45	89	134
+9·60	..	1	7	8	30	59	89
+9·80	2	2	3	7	19	32	51
+10·00	..	..	3	3	5	21	26
+10·20	..	..	..	..	7	14	21
+10·40	2	..	1	3	3	9	12
+10·60	1	..	..	1	..	10	10
+10·80	..	..	..	..	4	3	7
+11·00	..	..	..	..	1	..	1
+11·20	..	..	..	..	..	1	1
+11·40	..	..	..	..	..	1	1
+11·60	..	..	..	..	..	..	..
+11·80	..	..	..	..	..	..	..
+12·00	..	..	..	..	..	1	1
+12·20	..	..	..	..	..	..	..
Total	586	171	186	943	308	496	804
Mean Value	8·497	8·079	8·702	8·460	9·215	9·386	9·321
Standard Deviation	0·532	0·431	0·708	0·588	0·665	0·630	0·661
Coefficient of Variation (per cent)	6·3	5·3	8·1	6·9	7·2	6·7	7·1

Percentage total solids (Table 4)

The frequency distributions of the percentage of total solids in different groups of cows and buffaloes unlike those of the percentage butter-fat are symmetrical. The total solids content of buffaloes' milk is distinctly higher than that of cows' milk. The average total solids content varies a good deal from group to group of cows and of buffaloes. It is the highest in the village cows' milk and the least in the Holstein Sindhi's as was observed in the case of the butter-fat and the solids-not-fat contents. Likewise village buffaloes' milk contains more total solids than Murrah milk. The range is slightly smaller in cows' milk than in buffaloes'. It goes from 8·10 to 18·80 in cows and from 9·20 to 22·80 in buffaloes. The values of the standard deviation vary from 0·982 in Holstein Sindhi cows to 1·666 in village buffaloes. Relative to the mean, however, the variation is not so different in the different groups. The relative variation is much smaller for the percentage total solids than for the percentage butter-fat content. It is of the order of 10 per cent.

TABLE 4

Frequency distribution of Percentage Total Solids in fortnightly samples of milk of individual cows and buffaloes

Percentage Total Solids	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+8·40	2	..	..	2	..	..	..
+9·20	3	..	2	5	2	..	2
+10·00	4	2	1	7	2	..	2
+10·80	11	22	3	36	..	1	1
+11·60	70	62	11	143	3	2	5
+12·40	167	51	22	240	1	4	5
+13·20	174	18	35	227	3	8	11
+14·00	83	12	43	138	18	20	38
+14·80	45	3	35	83	48	47	95
+15·60	20	1	24	45	82	95	177
+16·40	4	..	7	11	79	105	184
+17·20	2	..	2	4	29	111	140
+18·00	1	..	1	2	23	46	69
+18·80	..	..	..	..	8	17	25
+19·60	..	..	..	..	4	22	26
+20·40	..	..	..	..	4	10	14
+21·20	..	..	..	..	1	6	7
+22·00	..	..	..	..	1	2	3
Total	586	171	186	943	308	496	804
Mean Value	13·444	12·538	14·302	13·449	16·407	17·002	16·774
Standard Deviation	1·204	0·982	1·455	1·337	1·629	1·666	1·675
Coefficient of Variation (per cent)	9·0	7·8	10·1	9·9	9·9	9·8	10·0

Percentage lactose (Table 5)

The frequency distributions of the percentage lactose, like those of the specific gravity, are asymmetrical with a long tail on the lower side of the mean value. The mean lactose content, like the mean butter-fat and the solids-not-fat content, varies from group to group much in the same fashion. Thus the mean lactose is more in the milk of village cows than in the milk of Red Sindhi cows and is more in the milk of Red Sindhi cows than in the milk of Holstein Sindhi cows. Among buffaloes, Murrah milk is poorer in lactose content than village milk. As between cows and buffaloes the latter's milk is richer.

The range of variation on the lower side of the mean value extends up to 2 per cent in cows' milk and 1·4 per cent in buffaloes' milk while on the upper side it goes up to 6·0 and 6·4 per cent respectively. The variation relative to the mean is of the order of 10 per cent.

The United Provinces, Bengal and Sind have prescribed 4·0 and 4·4 respectively as the minimum standards for the lactose content in milk of cows and buffaloes. The proportion of samples of individual cows' and buffaloes' milk falling below these values is considerable. The proportion falling below 4·0 per cent varies from 3 per cent in village buffaloes to 11 per cent in Holstein Sindhi cows. The proportion below 4·4 per cent varies from 12 to 45 per cent respectively. If, however, milk of a herd is pooled and then sold, the proportion decreases with the number of animals in the herd. In particular it will be shown later that when the herd consists of six animals or more, the proportion is negligible.

Percentage ash (Table 6)

The frequency distributions of the percentage ash in samples of milk of cows and of buffaloes are high-humped and almost symmetrical. The mean percentage ash in buffaloes' milk is significantly higher than that in cows' milk. Among the various groups of cows and buffaloes, the percentage ash in milk varies. The table shows that the milk of Red Sindhi cows has a higher ash content than the milk of Holstein Sindhis and the milk of Holstein Sindhi cows has a higher percentage ash than the milk of village cows. As compared with Murrahs' the village buffaloes' milk has a greater percentage of ash content. The mean value of percentage ash is 0·74 for all cows and 0·78 for all buffaloes.

The range varies from 0·60 to 0·92 in Holstein Sindhi cows and from 0·48 to 1·26 in Red Sindhi cows. The range is even larger for buffaloes' milk. The coefficient of variation is of the order of 8 per cent for cows' milk and 10 per cent for buffaloes' milk.

TABLE 5

Frequency distribution of Percentage Lactose in fortnightly samples of milk of individual cows and buffaloes

Percentage Lactose	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+1·40	..	..	..	..	1	..	1
+1·60	..	..	..	..	..	..	..
+1·80	..	..	..	..	..	..	..
+2·00	1	..	1	2	..	..	..
+2·20	..	..	2	2	..	..	..
+2·40	..	..	1	1	2	1	3
+2·60	1	..	..	1	1	..	1
+2·80	1	..	..	1	..	..	
+3·00	8	2	..	10	5	1	
+3·20	7	3	..	10	..	1	
+3·40	7	5	3	15	3	4	7
+3·60	15	7	4	26	1	2	
+3·80	18	7	4	29	7	7	
+4·00	32	22	3	57	8	13	
+4·20	58	31	9	98	19	29	48
+4·40	96	39	20	155	23	38	61
+4·60	148	33	31	212	44	49	93
+4·80	127	15	37	179	67	95	162
+5·00	47	6	34	87	80	141	221
+5·20	15	1	30	46	38	78	116
+5·40	4	0	16	10	6	32	38
+5·60	.	..	1	1	1	2	3
+5·80	1		.	1	1	3	4
+6·00			.		..		
+6·20			.	..	1	.	1
Total	586	171	186	943	308	496	804
Mean Value	4·584	4·393	4·786	4·589	4·809	4·924	4·880
Standard Deviation	0·458	0·416	0·562	0·488	0·535	0·426	0·474
Coefficient of Variation (per cent)	10·0	9·5	11·7	10·6	11·1	8·7	·7

Percentage crude protein (Table 7)

The frequency distributions of the percentage crude protein in samples of milk of individual cows and buffaloes are only slightly asymmetrical. Cows' milk is seen to contain a lower percentage of crude protein than buffaloes' milk. The mean percentage of crude protein in village cows' milk has a value of 3·312, while the corresponding value for buffaloes' milk is 3·797. The percentage content is different in different groups. It is least in the Holstein Sindhi cows' milk, being only 2·934.

The range of variation from sample to sample extends from 2·0 to 4·8 per cent in the case of cows' milk and 2·2 to 6·2 per cent in the case of buffaloes' milk. The variation relative to the mean as measured by the coefficient of variation is about the same in both cows' and buffaloes' milk and is of the order of 13 per cent.

TABLE 6

Frequency distribution of Percentage Lactose in fortnightly samples of milk of individual cows and buffaloes

Percentage Ash	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+0·440	..	..	..	..	1	1	2
+0·480	1	..	..	1	..	1	1
+0·520	2	..	..	2	1	3	4
+0·560	1	..	3	4	3	1	4
+0·600	16	2	4	22	4	4	8
+0·640	44	14	31	89	21	21	42
+0·680	111	54	52	217	47	59	106
+0·720	165	53	54	272	83	87	170
+0·760	146	37	30	213	68	111	179
+0·800	61	7	5	73	35	96	131
+0·840	23	3	2	28	26	57	83
+0·880	8	1	1	10	11	26	37
+0·920	1	..	2	3	3	13	16
+0·960	5	..	1	6	..	11	11
+1·000	..	..	..	..	1	4	5
+1·040	..	..	..	..	3	..	3
+1·080	..	..	..	..	1	..	1
+1·120	..	..	..	..	..	..	..
+1·160	..	..	..	..	..	..	..
+1·200	..	..	..	..	..	1	1
+1·240	2	..	..	2	..	..	..
Total	586	171	185	942	308	496	804
Mean Value	0·7516	0·7349	0·7249	0·7433	0·7652	0·7892	0·7800
Standard Deviation	0·0692	0·0467	0·0590	0·0647	0 0787	0·0825	0·0818
Coefficient of Variation (per cent)	9·21	6·38	8·08	8·70	10·28	10·45	10·48

TABLE 7

Frequency distribution of Percentage Crude Protein in fortnightly samples of milk of individual cows and buffaloes

Percentage Crude Protein	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+2·00	1	..	1	2	..	..	..
+2·20	3	5	2	10	1	1	2
+2·40	21	31	1	53	1	1	2
+2·60	72	40	6	118	1	4	5
+2·80	91	29	25	145	5	11	16
+3·00	126	28	53	207	15	21	36
+3·20	102	13	29	144	51	55	106
+3·40	76	20	29	125	46	85	131
+3·60	42	1	14	57	65	94	159
+3·80	33	1	10	44	46	86	132
+4·00	13	2	6	21	31	52	83
+4·20	4	1	6	11	21	35	56
+4·40	..	..	1	1	9	22	31
+4·60	2	..	..	2	5	15	20
+4·80	..	..	..	..	1	6	7
+5·00	..	..	..	..	3	3	6
+5·20	..	..	..	..	4	1	5
+5·40	..	..	..	..	2	2	4
+5·60	..	..	..	..	..	1	1
+5·80	..	..	..	..	..	..	..
+6·00	..	..	..	..	1	1	2
Total	586	171	183	940	308	496	804
Mean Value	3·208	2·934	3·312	3·178	3·763	3·797	3·784
Standard Deviation	0·406	0·384	0·409	0·420	0·500	0·502	0·498
Coefficient of Variation (per cent)	12·7	13·1	12·4	13·2	13·8	13·2	13·2

Percentage calcium oxide (Table 8)

The frequency distributions of the percentage calcium oxide in samples of milk of individual animals of different groups are more or less similar and symmetrical. As in the case of other characters, the buffaloes' milk is richer in calcium oxide content than cows' milk. The mean content is also different in the different groups of cows and buffaloes. Village buffaloes' milk has a percentage of 0·266 against the percentage value of 0·201 for the milk of the corresponding group of cows. The milk of village buffaloes is richer in the calcium content than the milk of Murrah buffaloes; the Red Sindhi cows' milk is richer than village and Holstein Sindhi cows' milk while the difference between village and Holstein Sindhi cows is of a magnitude that can be explained in terms of sampling errors and cannot therefore be ascribed to group differences.

Like the percentage butter fat, the percentage of calcium oxide also shows a large variation ranging from 0·0 to 0·4 in cows' milk and 0·1 to 0·5 in buffaloes' milk. The relative variation as measured by the coefficient of variation is of the order of 20 per cent.

TABLE 8

Frequency distribution of Percentage Calcium Oxide in samples of milk of individual cows and buffaloes

Percentage Calcium Oxide	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+0·000	..	1	..	1	..	.	..
+0·025	..	2	..	2	..	.	.
+0·050	..	..	..	..	..	..	.
+0·075	2	..	..	2	..	.	..
+0·100	2	3	1	6	.	1	1
+0·125	12	3	5	20	2	1	3
+0·150	25	14	14	53	5	3	8
+0·175	92	34	19	145	14	9	23
+0·200	85	17	16	118	31	37	68
+0·225	45	10	14	69	55	51	106
+0·250	18	4	5	27	28	60	88
+0·275	12	..	1	13	32	42	74
+0·300	6	..	1	7	10	31	41
+0·325	4	..	..	4	3	17	20
+0·350	1	..	..	1	3	6	9
+0·375	1	..	..	1	1	2	3
+0·400	..	..	..	..	.	1	1
+0·425	.	..	..	..	1	1	2
+0·450	..	..	..	..	.	.	..
+0·475	..	..	..	..	.	1	1
Total	305	88	78	471	185	263	448
Mean Value	0·2112	0·1883	0·2005	0·2051	0·2490	0·2664	0·2592
Standard Deviation	0·0427	0·0438	0·0383	0·0431	0·0375	0·0493	0·0482
Coefficient of Variation (per cent)	20·22	23·26	14·10	20·99	15·06	18·51	18·60

Percentage phosphorus pentoxide (Table 9)

The frequency distributions of the percentage phosphorus pentoxide in samples of milk of individual cows and buffaloes show a little positive skewness. As in the case of other characters, buffaloes' milk contains more of the phosphorus pentoxide than cows' milk. It varies from group to group of cows being the highest in Red Sindhi cows' milk and the least in Holstein Sindhi's milk. Between Murrahs and village buffaloes there is no statistically significant difference. The variation in the phosphorus pentoxide content from group to group is similar to that observed in the calcium oxide content and suggests a positive correlation between the two.

As in the case of calcium oxide content there is a large variation from sample to sample. The variation ranges from 0·10 to 0·50 in cows' milk and 0·10 to 0·55 in buffaloes' milk. The coefficient of variation is of the order of 20 per cent.

TABLE 9

Frequency distribution of Percentage Phosphorous Pentoxide in samples of milk of individual cows and buffaloes

Percentage Phosphoric Acid	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+0·100	..	..	1	1	..	..	..
+0·125	4	1	1	6	1	1	2
+0·150	12	14	6	32	..	1	1
+0·175	56	28	15	99	2	5	7
+0·200	76	25	29	130	20	15	35
+0·225	74	12	13	99	37	39	76
+0·250	46	3	6	55	52	82	134
+0·275	22	3	7	32	36	65	101
+0·300	8	1	..	9	16	29	45
+0·325	5		..	5	6	14	20
+0·350	..	..	1	1	3	9	12
+0·375	6	1	..	7	6	7	13
+0·400	2	..	..	2	3	2	5
+0·425	..	..	..	..	..	1	1
+0·450	1	..	..	1	1	2	3
+0·475	1	..	..	1	..	..	..
+0·500	..	..	..	..	..	..	..
+0·525	..	..	..	..	1	..	1
Total	313	88	79	480	184	272	456
Mean Value	0·2351	0·2070	0·2187	0·2272	0·2735	0·2794	0·2770
Standard Deviation	0·4500	0·0291	0·0394	0·0477	0·0514	0·0467	0·0486
Coefficient of Variation (per cent)	21·28	14·04	18·00	20·96	18·79	16·70	17·54

Percentage chlorine (Table 10)

The frequency distributions of the percentage of chlorine in samples of milk of individual animals are slightly skew in the positive direction. Unlike in the case of other characters cows' milk contains more of chlorine than buffaloes' milk. The mean chlorine content is 0·080 in the milk of village cows and 0·065 in the milk of village buffaloes. The milk of Holstein Sindhis is the richest in the chlorine content. There is no significant difference in mean values of the chlorine content of village and Red Sindhi cows' milk and also of village and Murrah buffaloes' milk.

There is a considerable variation in the values of the standard deviation for different groups, and consequently there is also variation in the values of the coefficient of variation which is of the order of 30 per cent. Of all constituents this appears to be the most variable one.

Percentage true protein (Table 11)

Compared to other characters, there is only a small number of samples giving the values of the percentage true protein. It is consequently difficult to speak with the same degree of confidence as in the case of other characters about the form and the nature of the frequency distributions. In general it may be said that the distributions are slightly skew in the positive direction. The mean true protein content is higher in buffaloes' milk than in cows' milk. It also varies from group to group of cows being the highest in village cows' milk and the lowest in Holstein Sindhi cows' milk. There is no material difference in the true protein content of Murrah and village buffaloes' milk. This is also a fairly variable character, the coefficient of variation being about 12 per cent.

TABLE 10

Frequency distribution of Percentage Chlorine in samples of milk of individual cows and buffaloes

Percentage Chlorine	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+0·000	1	..	1	2	..	1	1
+0·010	1	..	..	1	3	..	3
+0·020	3	..	3	6	5	6	11
+0·030	9	..	3	12	6	6	12
+0·040	20	3	4	27	13	48	61
+0·050	41	1	19	61	58	96	154
+0·060	54	4	32	90	48	68	116
+0·070	55	11	29	95	31	59	90
+0·080	24	9	21	54	22	22	44
+0·090	37	13	9	59	6	8	14
+0·100	23	12	7	42	4	9	13
+0·110	18	26	6	50	3	6	9
+0·120	11	16	3	30	2	..	2
+0·130	6	12	1	19	2	2	4
+0·140	5	5	..	10	..	..	..
+0·150	6	7	3	16	..	..	..
+0·160	9	6	1	16	2	..	2
+0·170	..	..	2	2	..	..	..
+0·180	1	..	..	1	..	..	..
+0·190	..	..	..	..	..	..	..
+0·200	..	..	..	..	..	..	..
+0·210	..	..	..	..	..	..	..
+0·220	..	..	..	..	..	..	..
+0·230	..	..	1	1	..	..	..
Total	324	125	145	594	205	331	536
Mean Value	0·0831	0·1113	0·0795	0·0883	0·0671	0·0645	0·0655
Standard Deviation	0·0312	0·0277	0·0305	0·0327	0·0220	0·0181	0·0197
Coefficient of Variation (per cent)	37·55	24·80	38·36	37·09	32·82	28·06	30·12

TABLE 11

Frequency distribution of Percentage True Protein in samples of milk of individual cows and buffaloes

Percentage True Protein	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+1·80	1	1	..	2	..	..	..
+2·00	2	9	..	11	..	..	..
+2·20	7	14	1	22	..	..	..
+2·40	17	6	7	30	1	1	2
+2·60	21	13	5	39	4	3	7
+2·80	29	3	7	39	13	7	20
+3·00	16	5	9	30	9	17	26
+3·20	6	..	2	8	15	21	36
+3·40	4	..	4	8	14	25	39
+3·60	4	..	2	6	12	16	28
+3·80	1	..	2	3	3	9	12
+4·00	..	..	..	..	1	2	3
+4·20	1	..	..	1	2	..	2
+4·40	..	..	..	..	..	..	..
+4·60	..	..	..	..	1	1	2
Total	109	51	39	199	75	102	177
Mean Value	2·855	2·501	3·013	2·798	3·350	3·413	3·386
Standard Deviation	0·382	0·321	0·412	0·422	0·412	0·350	0·376
Coefficient of Variation (per cent)	13·4	12·8	13·7	15·1	12·3	10·3	11·1

Percentage non-protein nitrogen (Table 12)

The determination of the percentage of non-protein nitrogen is based on the same number of samples as that of the percentage true protein. The frequency distributions appear to be more or less symmetrical for all groups, but are somewhat more spread out in buffaloes than in cows. There is a significant difference in the mean value of the percentage of non-protein nitrogen in the milk of cows and of buffaloes, being 0·054 in the former and 0·051 in the latter. As between the groups of cows, however, there is no difference but the milk of Murrah buffaloes contains a significantly larger percentage of non-protein nitrogen than the milk of village buffaloes. There is considerable variation in this character also. The coefficient of variation is 25 per cent for cows and is of the order of 30 per cent for buffaloes.

TABLE 12

Frequency distribution of Percentage Non-Protein Nitrogen in samples of milk of individual cows and buffaloes

Percentage Non-Protein Nitrogen	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+0·005	..	..	1	1	..	..	..
+0·010	..	..	..	..	1	1	2
+0·015	1	..	..	1	1	2	3
+0·020	1	..	1	2	2	4	6
+0·025	2	..	..	2	3	3	6
+0·030	4	4	..	8	2	11	13
+0·035	5	5	6	16	6	12	18
+0·040	16	1	3	20	4	9	13
+0·045	11	7	7	25	11	16	27
+0·050	16	9	8	33	5	14	19
+0·055	20	9	7	36	13	11	24
+0·060	11	6	2	19	7	3	10
+0·065	13	2	2	17	8	7	15
+0·070	2	3	2	7	8	2	10
+0·075	2	2	..	4	3	1	4
+0·080	2	2	..	4	..	1	1
+0·085	1	..	..	1	..	..	..
+0·090	..	1	..	1	..	1	1
+0·095	2	..	..	2	1	1	2
Total	109	51	39	199	75	99	174
Mean Value	0·0548	0·0558	0·0503	0·0542	0·0543	0·0479	0·0507
Standard Deviation	0·0140	0·0139	0·0125	0·0138	0·0161	0·0152	0·0160
Coefficient of Variation (per cent)	25·63	24·97	24·85	25·45	29·62	31·77	31·50

Percentage casein (Table 13)

The distributions of the percentage casein are also based on about the same number of samples as those of the percentage true-protein and non-protein nitrogen. The distributions show a tendency towards positive skewness. Buffaloes' milk contains a higher percentage of casein than cows' milk. As between the groups of cows, there is a significant variation, the mean percentage value varying from 2·1 in Holstein Sindhi cows' milk to 2·6 in the milk of village cows. There is no difference in the casein content of Murrah and village buffaloes' milk. There is a large variation from sample to sample, the coefficient of variation being 15 per cent for cows and 10 per cent for buffaloes.

Percentage albumin (Table 14)

The determination of the percentage albumin is also based on about the same number of samples as that of the above three characters. There is no evidence that the percentage of albumin is significantly different in the milk of different groups of cows and of buffaloes. Even as between all cows and all buffaloes, it cannot be asserted that the percentage albumin differs significantly. The character is very variable and has a coefficient of variation of the order of 30 per cent.

TABLE 13

Frequency distribution of Percentage Casein in samples of milk of individual cows and buffaloes

Percentage Casein	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+1·40	1	..	..	1	..	..	..
+1·60	1	3	..	4	..	..	..
+1·80	8	15	..	23	..	..	..
+2·00	20	15	4	39	..	..	..
+2·20	27	12	11	50	3	1	4
+2·40	33	6	6	45	5	9	14
+2·60	9	1	8	18	14	14	28
+2·80	8	..	4	12	12	26	38
+3·00	4	..	3	7	19	24	43
+3·20	2	..	2	4	10	19	29
+3·40	..	..	1	1	5	6	11
+3·60	1	..	..	1	..	..	..
+3·80	..	..	..	..	..	1	1
+4·00	..	..	..	..	1	1	2
Total	114	52	39	205	69	101	170
Mean Value	2·419	2·128	2·602	2·380	2·983	3·016	3·003
Standard Deviation	0·349	0·237	0·359	0·363	0·269	0·312	0·320
Coefficient of Variation (per cent)	14·4	11·1	13·8	15·3	9·0	10·3	10·7

TABLE 14

Frequency distribution of Percentage Albumin in samples of milk of individual cows and buffaloes

Percentage Albumin	Cows				Buffaloes		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
+0·00	3	2	..	5	..	..	..
+0·10	2	..	1	3	..	..	..
+0·20	17	9	7	33	17	18	35
+0·30	34	20	15	69	36	34	70
+0·40	31	13	7	51	10	32	42
+0·50	11	4	6	21	4	9	13
+0·60	4	1	..	5	1	2	3
+0·70	5	1	1	7	..	..	..
+0·80	2	..	..	2	..	..	..
+0·90	..	..	..	..	..	1	1
Total	109	50	37	196	68	96	164
Mean Value	0·415	0·381	0·392	0·402	0·361	0·401	0·383
Standard Deviation	0·154	0·126	0·118	0·141	0·088	0·113	0·099
Coefficient of Variation (per cent)	27·1	33·0	30·0	35·1	24·4	28·1	25·7

Freezing point-depression (Table 15)

The numbers of determinations of the freezing point depression for each of several groups are even smaller than for true-protein, non-protein nitrogen, casein and albumin but even so the numbers of observations are larger than any so far collected in India. The frequency distributions are more or less symmetrical. The freezing point depression has a higher value for cows' milk than for buffaloes' milk but as between the various groups of cows and of buffaloes there does not appear to be any significant difference. The mean value of the freezing point depression is 0·546 for cows' milk and 0·543 for buffaloes' milk. Like specific gravity this physical character of milk is also remarkably constant from sample to sample, the coefficient of variation being only of the order of 2 per cent.

TABLE 15

Frequency distribution of Freezing Point Depression in samples of milk of individual cows and buffaloes

Freezing Point Depression	COWS				BUFFALOES		
	Red Sindhi	Holstein Sindhi	Village	All	Murrah	Village	All
—0·510	..	..	..	.	1	1	2
—0·515	..	..	..	..	..	.	.
—0·520	2	..	..	2	..	1	1
—0·525	4	1	2	7	3	2	5
—0·530	3	2	1	6	7	9	16
—0·535	8	7	2	17	11	13	21
—0·540	16	7	7	30	11	24	35
—0·545	15	1	3	19	9	22	31
—0·550	14	4	5	23	10	13	23
—0·555	2	2	2	6	5	3	8
—0·560	7	1	3	11	4	3	7
—0·565	3	..	5	8	2	3	5
—0·570	2	..	1	3	..	..	..
—0·575	2	..	1	3	1	..	1
—0·580	..	..	..	..	..	..	..
—0·585	..	..	..	..	..	1	1
Total	78	25	32	135	64	95	159
Mean Value	0·5454	0·5410	0·5492	0·5455	0·5429	0·5424	0·5426
Standard Deviation	0·0120	0·0088	0·0132	0·0120	0·0116	0·0103	0·0108
Coefficient of Variation (per cent)	2·20	1·63	2·40	2·20	2·14	1·90	1·99

3. VARIATION IN THE COMPOSITION OF MIXED AND TONED MILK

Milk which is sold in the market and reaches the homes of consumers is not always the milk of individual animals but is also the mixed milk of several cows or buffaloes or both. Often the milk that reaches homes is also toned to a uniform fat content by the addition of skim milk. It is, therefore, important for us to know the composition of mixed milk from herds of several animals.

In India little or no data regarding the composition of mixed or toned milk are available. At the Institute an attempt has been made to determine the composition of mixed milk of animals of the Sindhi and the Murrah herds. The determinations were made on 38 samples of each herd but the number of animals from sample to sample has varied. In the Red Sindhi herd the number of animals has varied from 10 to 19 and in the Murrah herd it has varied from 8 to 18. Table 16 shows the values of the mean and the standard deviation of the constituents and other characters of milk for these 38 samples and also the corresponding values for the milk of individual animals. A comparison of the mean values shows that there is no significant difference in the mean composition of mixed milk of the Murrah herd and the mean composition of milk of individual Murrah animals. In the case of the Red Sindhi herd, however, the mean values of 4 out of the 11 characters show a somewhat larger departure than can be explained at the 5 per cent level of significance on chance theory. Even so the differences are not great and it may be said that the mean composition of mixed milk agrees within sampling errors with the composition of milk of individual animals. The comparison in respect of the values of the standard deviation shows that the constituents of the milk of herds are much less variable than those of the milk of individual animals. The table shows that the values of the standard deviation for mixed milk are about a quarter of the corresponding values for the milk of individual animals. This is as it should be, since the standard deviation of a character of the milk of a herd of 'n' random animals is expected within sampling errors to be equal to $1/\sqrt{n}$ times the corresponding value for individual animals. Our data do not permit a rigid statistical comparison on this basis, since the number of animals in the herd has varied from sample to sample. In the Sindhi herd the number of animals has varied from 10—19 with an average of 15 animals; in the Murrah herd the number of animals has varied from 8—18 with an average of 11. It is also not strictly permissible to assume that the size of the herd from sample to sample has remained constant at the average size of the herd but a comparison on this basis shows that even with differing number of animals from sample to sample the sampling law is approximately realised. The table shows that with the exception of chlorine in the Red Sindhi herd and specific gravity, fat and total solids in the Murrah herd the standard deviations of all the other characters have decreased in the ratio inversely as the square root of the average number of animals in the herd. The asterisks against these characters in the Sindhi and the Murrah herds show that the departure of the observed values of the standard deviations of these characters from those expected on the sampling theory are larger than can be explained in terms of pure change causes, but it is noteworthy that even with a change in the size of the herd from sample to sample these departures are not great.

TABLE 16

Showing the composition of mixed milk and the composition of milk in individual animals

		Red Sindhi cows		Murrah buffaloes	
		Mixed milk	Individual milk	Mixed milk	Individual milk
Percentage butter fat	N†	38	586	38	308
	Mean	4·813	4·925	7·057	7·161
	St. Dev.‡	0·219	0·970	0·639*	1·375
Percentage solids-not-fat	N	38	586	38	308
	Mean	8·438	8·497	9·142	9·215
	St. Dev.	0·142	0·532	0·255*	0·665
Percentage total solids	N	38	586	38	308
	Mean	13·252*	13·444	16·199	16·407
	St. Dev.	0·242	1·204	0·716*	1·629
Percentage lactose	N	36	586	36	308
	Mean	4·760	4·584	4·801	4·809
	St. Dev.	0·107	0·458	0·137	0·535
Percentage ash	N	38	586	38	308
	Mean	0·7532	0·7516	0·7749	0·7652
	St. Dev.	0·0149	0·0692	0·0296	0·0787
Percentage crude protein	N	38	586	37	308
	Mean	3·122*	3·208	3·709	3·763
	St. Dev.	0·096	0·406	0·161	0·500
Percentage calcium oxide	N	19	305	19	185
	Mean	0·1923*	0·2112	0·2391	0·2490
	St. Dev.	0·0104	0·0427	0·0201*	0·0375
Percentage phosphorus pentoxide	N	19	313	19	184
	Mean	0·2241*	0·2351	0·2674	0·2735
	St. Dev.	0·0129	0·0500	0·0161	0·0514
Percentage chlorine	N	37	324	38	205
	Mean	0·0790	0·0831	0·0667	0·0671
	St. Dev.	0·0060*	0·0312	0·0054	0·0220
Specific gravity	N	38	586	38	308
	Mean	1·03100	1·03088	1·0317	1·03122
	St. Dev.	0·00056	0·00188	0·00114*	0·00266
Freezing point depression	N	6	78	6	64
	Mean	0·5458	0·5454	0·5400	0·5429
	St. Dev.	0·0017	0·0120	0·0063	0·0116

* indicates significance at 5 per cent level of probability.
† N = Number of samples.
‡ St. Dev. = Standard deviation.

In table 17 are given the data relating to toned milk alongside with the corresponding data for individual animals. The table shows that the composition of toned milk of the Red Sindhi herd was determined on 32 samples, while that of the Murrah herd toned to 3·5 and 5 per cent fat respectively was determined on 34 samples each. As in the case of samples of the mixed milk the size of herd in different samples of the toned milk has also varied. The number of animals has varied from 10—18 in the different samples of toned milk of the Red Sindhi herd and the number has varied from 13—18 in the case of milk of the Murrah herd. This flaw of varying size of herd in different samples does not, as we have already observed, permit a strict comparison of the mean values and the standard deviations of the characters of the toned milk with the corresponding values for milk of the individual animals. Nevertheless, a comparison on the basis of the average size is of some interest. Such a comparison shows that excepting the freezing point value and possibly phosphorus pentoxide and crude protein the mean composition of toned milk of the Red Sindhi herd is significantly different from that of milk of the individual animals. The comparison of the mean composition of toned milk of the Murrah herd with the corresponding composition in the individual animals points to the same conclusions. There is, however, one important difference. It will be seen that the composition of milk toned to 5 per cent fat is more alike to the mean composition of milk of individual animals than is the composition of milk toned to 3.5 per cent. This is as it should be, since the milk toned to 5 per cent fat displaces only 2·161 per cent of true butter fat, whereas the milk toned to 3·5 per cent fat displaces a much larger amount, namely 3·661. In regard to the sampling variation of the characters, it will be observed that the variation in butter fat content of toned milk is almost negligible as indeed would be expected since the content of each sample has been adjusted to a fixed value. The sampling variation in characters other than butter

fat content is seen to be much less than the corresponding variation in the milk of individual animals. In fact it will be seen that the standard deviations of most characters are, as in the previous case, approximately equal to a quarter of the corresponding values in the individual animals. This is also expected since the toned milk whose composition we are considering is a mixed milk of several animals and, on the sampling theory, we should expect the variation in a random group of 'n' animals to be reduced inversely as the square root of n, and n in the present case is approximately equal to 15 for the Red Sindhi herd and 14 for the Murrah herd.

TABLE 17

Showing the composition of toned milk and composition of milk in individual animals

		Red Sindhi cows		Murrah buffaloes		
		Toned milk 3·5% butter fat	Individual milk	Toned milk 3·5% butter fat	Toned milk 5% butter fat	Individual milk
Percentage butter fat	N†	32	586	24	24	308
	Mean	3·510*	4·925	3·533*	5·026*	7·161
	St. Dev.‡	0·066*	0·970	0·065*	0·075*	1·375
Percentage solids-not-fat	N	32	586	24	24	308
	Mean	8·632*	8·497	9·644	9·369*	9·215
	St. Dev.	0·125*	0·532	0·498*	0·305*	0·665
Percentage total solids	N	32	586	24	24	308
	Mean	12·142*	13·444	13·177*	14·395*	16·407
	St. Dev.	0·149	1·204	0·492	0·292	1·6290
Percentage lactose	N	31	586	24	24	308
	Mean	4·823*	4·584	5·065*	4·986	4·809
	St. Dev.	0·109	0·458	0·138	0·136	0·535
Percentage ash	N	32	586	24	24	308
	Mean	0·7617*	0·7516	0·7987*	0·7860*	0·7652
	St. Dev.	0·0141	0·0692	0·0311	0·0319	0·0787
Percentage crude protein	N	32	586	24	24	308
	Mean	3·149	3·208	3·760	3·725	3·763
	St. Dev.	0·105	0·406	0·241*	0·216*	0·500
Percentage calcium oxide	N	15	305	11	11	185
	Mean	0·1949	0·2112	0·2385	0·2366	0·2490
	St. Dev.	0·0171	0·0427	0·0189	0·0197	0·0375
Percentage phosphorus pentoxide	N	14	313	11	11	184
	Mean	0·2251	0·2351	0·2760	0·2694	0·2735
	St. Dev.	0·0114	0·0500	0·0149	0·0203	0·0514
Percentage chlorine	N	30	324	24	23	205
	Mean	0·0768*	0·0831	0·0680	0·0674	0·0671
	St. Dev.	0·0062	0·0312	0·0049	0·0053	0·0220
Specific gravity	N	32	586	24	24	308
	Mean	1·0328*	1·03088	1·0358*	1·0338*	1·03122
	St. Dev.	0·0007*	0·00188	0·00109*	0·00087	0·00266
Freezing point depression	N	8	78	7	6	64
	Mean	0·5450	0·5454	0·5400	0·5400	0·5429
	St. Dev.	0·0060	0·0120	0·0041	0·0071	0·0116

* Indicates significance at 5 per cent level of probability.
† N—Number of samples.
‡ St. Dev.—Standard deviation.

Table 18 gives data for the mixed milk of herds composed both of cows and buffaloes. On the average the Indalpur herd consists of 6 cows and 34 buffaloes, the Ganeshganj herd consists of 8 cows and 42 buffaloes, the Iradatganj herd consists of 6 cows and 13 buffaloes, while the Institute herd consists of 56 cows and 11 buffaloes. The numbers of samples on which the composition has been determined are small; the numbers are 17 for the Indalpur herd, 19 for the Ganeshganj herd, 14 for the Iradatganj herd and only 7 for the Agricultural Institute herd. The data suffer from the same defect as those for the mixed and toned milk of herds. The numbers of animals in these herds have varied from sample to sample and have varied very widely in this particular case. Thus in the Indalpur herd the number of cows has varied from 4 to 9 and the number of buffaloes varied from 18 to 51. In the Ganeshganj herd the number of cows has varied from 5 to 12 and the number of buffaloes varied from 23 to 54. Likewise the variations in the Iradatganj herd are from 4 to 8 for cows and 8 to 20 for buffaloes. The Agricultural Institute herd had more or less the same number

in different samples. The number of cows varied from 55 to 58 and the number of buffaloes from 10 to 11. This advantage is, however, offset by the smallness of the number of samples. There is also one additional defect in these data. Not only are the numbers of animals different from sample to sample but even the proportion of the number of cows to the number of buffaloes has considerably changed. If a mixed herd of random animals consists of N_1 cows and N_2 buffaloes, and further if $\bar{x}_1$, s_1 and $\bar{x}_2$, s_2 denote the mean values and the standard deviations of any character of milk in n_1 and n_2 samples respectively (each sample from one animal), then we should on the sampling theory, expect that the value of that character in the milk of all samples mixed together will be approximately equal to $\frac{n_1\bar{x}_1+n_2\bar{x}_2}{n_1+n_2}$ and the standard deviation of the character in the herd will be equal to $\frac{\sqrt{n_1s_1^2+n_2s_2^2}}{n_1+n_2}$. On account of the defects mentioned above, however, it seems hardly fair to institute a comparison between the observed values of the means and the standard deviations with those expected on the above theory. We may, however, note in passing that the values of the standard deviation in characters of the mixed herd are smaller than the corresponding values in the individual animals.

Table 18

Showing the composition of milk of mixed herds and composition of milk of individual animals

		Indalpur mixed herd	Ganeshganj mixed herd	Iradatganj mixed herd	Agricultural Institute herd	Individual milk	
						Village cows	Village buffaloes
Percentage butter fat	N*	17	19	14	7	186	496
	Mean	6·782	7·405	7·338	6·237	5·607	7·624
	St. Dev.†	0·879	0·760	0·683	0·518	1·234	1·598
Percentage solids-not-fat	N	16	19	13	7	186	496
	Mean	8·566	9·011	9·107	8·666	8·702	9·386
	St. Dev.	0·618	0·496	0·319	0·118	0·708	0·630
Percentage total solids	N	16	19	13	7	186	496
	Mean	15·409	16·417	16·548	14·903	14·302	17·002
	St. Dev.	1·355	1·054	0·651	0·597	1·455	1·666
Percentage lactose	N	16	19	13	7	186	496
	Mean	4·708	4·862	4·892	4·760	4·786	4·924
	St. Dev.	0·363	0·185	0·150	0·072	0·562	0·426
Percentage ash	N	16	19	12	7	185	496
	Mean	0·7135	0·7653	0·7448	0·7353	0·7249	0·7892
	St. Dev.	0·0440	0·0468	0·0232	0·0074	0·0590	0·0825
Percentage crude protein	N	16	19	13	7	183	496
	Mean	3·520	3·642	3·654	3·410	3·312	3·797
	St. Dev.	0·295	0·295	0·159	0·196	0·409	0·502
Percentage calcium oxide	N	7	9	6		78	263
	Mean	0·2210	0·2402	0·2247		0·2005	0·2664
	St. Dev.	0·0080	0·0261	0·0151		0·0383	0·0493
Percentage phosphorus pentoxide	N	7	9	6		79	272
	Mean	0·2474	0·2616	0·2623		0·2187	0·2794
	St. Dev.	0·0139	0·0204	0·0064		0·0394	0·0467
Percentage chlorine	N	16	19	13		145	331
	Mean	0·0594	0·0595	0·0565		0·0795	0·0645
	St. Dev.	0·0076	0·0101	0·0078		0·0305	0·0181
Specific gravity	N	17	19	14	7	186	496
	Mean	1·0298	1·0310	1·0310	1·0310	1·03104	1·03156
	St. Dev.	0·00210	0·00200	0·00201	0·00068	0·00274	0·00242
Freezing point depression	N	6	7	6		32	95
	Mean	0·5225	0·5269	0·5280		0·5492	0·5426
	St. Dev.	0·0398	0·0178	0·0145		0·0132	0·0103

* N = Number of samples
† St. Dev. = Standard deviation.

4. COMPARISION OF THE AVERAGE COMPOSITION OF MILK DERIVED FROM THE ALLAHABAD DATA WITH THAT OBTAINED BY OTHER WORKERS IN INDIA AND ABROAD

No comprehensive survey of Indian data on the composition of milk has so far been made. From the view-point of fixing standards for the quality of milk, it is of value to collect and collate these results and note the variations at least among the chief constituents of milk. A large amount of data has been received by us from the various Research and Government Laboratories in India. In this report we propose to give only a summary table reporting these data and to compare the results with those we have obtained in this investigation. A comparison of the average composition of Indian cows' milk will also be made with that of Western cows' milk.

Tables 19 and 20 show the average composition of milk with regard to contents of fat and solids-not-fat according to the various authorities. Tables 21 and 22 show the average composition with regard to other constituents. Results of individual and herd samples have been separately reported in the tables. Cases where the average composition reported to us was based on less than five samples have been omitted. The last row of each table gives the averages for all data.

It is not claimed that the comparison of the averages of these data with ours is strictly fair. The difficulties with respect to the variations in the method of chemical analysis, particularly in the methods of determining the solids-not-fat and its constituents, with respect to the nature of the samples whether morning, evening or bulk included in these averages, and others are doubtless present. We also cannot say whether the data reported to us from Government and other laboratories were representative of the average quality of milk in those places.

It will be seen from Tables 19 and 20 that there is a considerable variation in the average butter fat and solids-not-fat content reported by various authorities. This is to be expected on account of different breeds, different places and partly different methods of analysis. It should, however, be noted that no authority reports less than ·4 per cent of butter fat in cows' milk and 6 per cent in buffaloes' milk. These percentage limits, as will be seen later, are well above the existing standards for butter fat in India. As against this the values of the average percentage of solids-not-fat are, in more than half the number of cases reported to us, less than the prescribed standard of 8·5 in India. In buffaloes' milk they vary from 9·12 to 11·81.

It will be seen from Table 19 that the values 4·83 and 8·38 for the average percentage butter fat and solids-not-fat respectively in samples of individual cows' milk agree well with the corresponding values 4·97 and 8·46 obtained by us. Likewise the average values relating to individual samples of buffaloes' milk shown in Table 20 show a fair agreement with our values. The corresponding comparison for samples of herd milk, however, shows a discrepancy, particularly in the values of solids-not-fat content, possibly due to the inclusion of a disproportionately larger number of low quality samples to which the suspicion of Public Health and Municipal Authorities must have been directed during the course of selecting samples for checking their quality and also possibly due to the use of Richmond's scale which, as will be shown later, over-estimates the true content of solids-not-fat in milk.

A comparison of the average value for ash content shown in Table 21 with the corresponding value obtained by us shows a close agreement. Results for other constituents namely lactose, crude protein, phosphorus pentoxide and calcium oxide are reported by only a few authorities. In the case of the last three constituents the number of samples on which the determinations were made is also unknown. A comparison of the average values for these constituents with those obtained by us under these circumstances can hardly be said to be fair. Even so, such comparison shows a fair amount of agreement between the two sets of values. For buffaloes' milk the averages for ash, phosphorus pentoxide and calcium oxide from all data reported in Table 22 compare well with the corresponding values obtained by us. The values for lactose and crude protein are reported by just one and two authorities respectively. In both cases the number of samples on which the averages were based is unknown. We have, therefore, no means of knowing the reliability of these values reported to us. A comparison with our values shows that the lactose content reported to us is rather low while the percentage crude protein reported is much larger.

TABLE 19

Average composition of cows' milk with regard to fat and solids-not-fat according to various authorities

Source of data	Breed	Type of sample Herd (H) & Individual (I)	Number of samples	Fat %	Solids-not-fat %
I.A.R.I., Delhi	Sahiwal	I	25	4·57	8·44
Ditto	Do	I	12	4·92	..
Ditto	Do	I	24	5·00	..
Dacca Farm	Sindhi	I	6	3·98	8·40
Surat Govt. Farm	....	I	26	4·70	..
Agricultural College Dairy (Coimbatore)	Cross	I	10	5·80	8·20
Average (weighted)			103	4·83	8·38
Public Health Inst., Bangalore	Mysore	H	196	4·24	9·60
Agricultural Sub-Station, Karnal	Tharparkar	H	52	4·60	..
Mymensing	....	H	16	4·64	..
Faridpore	....	H	15	4·50	..
Telankheri Dairy Farm, Nagpur	....	H	22	4·98	8·19
Ditto	....	H	22	4·99	8·23
Ditto	....	H	22	4·51	8·24
Bengal Public Health Laboratory, Calcutta	....	H	100	5·20	9·01
Military Dairy, Murree	....	H	45	4·25	8·94
Salvation Army Dairy, Lahore	....	H	47	5·46	9·33
Gowalas (Lahore City)	....	H	48	4·18	9·14
Average (weighted)			585	4·61	9·17
Average (all data)			688	4·64	9·11

TABLE 20

Average composition of buffaloes' milk with regard to fat and solids-not-fat according to various authorities

Source of data	Breed	Type of sample Herd (H) Individual (I)	Number of samples	Fat %	Solids-not-fat %
College Dairy, Nagpur	Murrah buffaloes	I	10	6·37	10·15
Ditto	Ditto	I	8	6·74	9·71
Ditto	Surat & Murree Buffaloes	I	8	8·48	9·70
Ditto	Ditto	I	6	9·48	9·93
Ditto	Ditto	I	40	7·82	9·54
Average (weighted)			72	7·71	9·69
College Dairy, Nagpur	Cross	H	25	8·40	9·39
Ditto	Do.	H	10	9·38	9·25
Ditto	Do.	H	22	8·30	10·14
Military Dairy Murree	Murrah	H	48	7·26	9·39
Public Health Institute, Bangalore	Dharwar Buffaloes	H	50	6·20	11·18
Municipalities of Rawalpindi, Kujar Khan, etc.		H	298	6·28	10·09
Public Health Department, Poona (1936)	....	H	32	6·58	9·78
Ditto (1937)	....	H	7	6·37	9·43
Surat 1936	....	H	27	6·27	9·30
Surat 1937	....	H	29	6·06	9·12
Military Dairy Farm, Lahore Cantonment	....	H	62	6·79	9·69
Gowalas in Lahore city	....	H	41	6·61	9·92
Public Health Institute (Bangalore)	Gujrat breed	H	38	6·46	11·81
Average (weighted)			689	6·61	10·04
Average (all data)			761	6·71	10·01

TABLE 21

Average composition of cows' milk with regard to other constituents according to various authorities

Source of data	Breed	Type of sample	No. of samples	Ash	Lactose	Crude protein	P_2O_5	CaO
Military Dairy Farm, Lahore Cantonment.	....	H	62	0·77	4·35	..	..	..
Gowalas in Lahore City	....	H	41	0·79	4·40	..	..	..
Public Health Inst., Bangalore	Gujrat	H	38	0·81	..	..	..	..
Military Dairy, Murree	....	H	45	0·73	..	..	..	..
Salvation Army Dairy, Lahore	....	H	47	0·72	4·21	..	..	..
Public Health Institute, Bangalore	English cows	H	18	0·63	..	..	..	..
Nutrition Research Laboratory, Conoor.	....	H	..	0·70	..	3·30	0·21	0·170
A.I.I.H. & P.H., Calcutta	....	H	..	0·70	4·80	3·30	0·21	0·167
Average (unweighted)				0·73	4·44	3·30	0·21	0·169

TABLE 22

Average composition of buffaloes' milk with regard to other constituents according to various authorities

Source of data	Breed	Type of sample	No. of samples	Ash	Lactose	Crude Protein	P_2O_5	Ca O
College Dairy, Nagpur	Murrah	I	10	0·84	..	..	0·27	0·306
Ditto	Do.	I	8	0·75	..	..	0·25	0·264
Ditto (1931)	Surat & Murree	I	8	0·72	..	..	0·28	0·233
Ditto (1931)	Do.	I	6	0·86	..	..	0·33	0·317
Ditto (1932)	Do.	I	40	0·72	..	..	0·24	0·250
Ditto	Cross	II	25	0·84	..	..	0·27	0·275
Ditto	Do.	II	10	0·85	..	..	0·29	0·280
Ditto	Do.	II	22	0·82	..	..	0·29	0·280
Military Dairy, Murree (1922)	Murree & Delhi	II	48	0·76	..	..	..	..
Public Health Inst., Bangalore	Dharwar Buffaloes	H	50	0·78	..	..	..	..
Coonoor Nutrition Research Laboratory.	....	H	..	0·80	..	4·3	0·30	0·290
A.I.I.H. & P.H., Calcutta	....	H	..	0·80	4·45	4·75	0·28	0·284
Average (unweighted, all data)				0·80	4·45	4·52	0·28	0·278

Table 23 includes the composition of milk of Western cows according to various authorities as given by Davies (28). The last two rows of the table show the averages of all Western and Indian data including those reported to us. The table shows that the composition of Indian cows' milk is different mainly in two respects from the composition of Western cows' milk; (*a*) the total solids content of Indian cows' milk is higher and (*b*) the butter fat content is still higher. The Indian cows' milk on the average is richer by about 0·8 per cent in the total soilds content and richer by over 1 per cent in the butter fat content. The solids-not-fat content of Indian cows' milk is accordingly less by 0.3 per cent. Protein (casein and Albumin) and lactose which mainly make up the solids-not-fat content of milk are also distinctly lower in Indian cows' milk as compared with the Western cows but ash content shows no appreciable difference in the two. Veith's ratio of 13:9:2 for Western cattle is obviously inapplicable The average proportion of lactose, protein and ash in Indian cows' milk is 12·5:7·5:2. It is of interest to note that Veith's ratio for buffaloes' milk is 12·5:9·7:2,

TABLE 23

Detailed Composition of Milk: per cent of whole milk

Authority	Water	Fat	Casein	Albumin	Total protein	Lactose	Ash	Total solids
Van Slyke	87·1	3·9	2·5	0·7	3·2	5·1	0·7	12·9
Babcock	87·3	3·6	3·0	0·6	3·8	4·5	0·7	12·7
Willoughby	87·0	3·8	3·3	0·4	3·7	4·8	0·7	13·0
Oliver	87·6	3·25	3·40	0·45	3·85	4·55	0·75	12·4
Richmond	87·1	3·9	3·0	0·4	3·4	4·75	0·75	12·9
Fleischmann	87·75	3·40	2·80	0·70	3·50	4·60	0·75	12·25
Rogers	87·27	3·66	2·95	0·52	3·47	4·91	0·65	12·73
Tocher	87·25	3·95	2·42	0·74	3·16	4·64	0·70	12·75
Cranfield	87·54	3·71	..	..	3·25	(4·74)*	0·76	12·46
Farrington and Woll	87·4	3·7	..	..	3·2	5·0	0·7	12·6
Abder-halden	..	3·70	2·90	0·50	3·40	4·95	..	..
Cornevin	87·75	3·30	3·00	..	..	4·80	0·75	12·75
Golding et al	87·21	3·88	2·60	..	..	4·74	0·77	12·79
Davies	..	..	2·48	0·57	3·05	..	..	..
Average western cows' milk (all data)	..	3·67	2·86	0·56	3·42	4·78	0·73	12·69
Average Indian cows' milk	..	4·83	2·38	0·40	2·78	4·56	0·74	13·52

* Calculated by difference

5. MILK STANDARDS

The quality of milk of commerce is defined mainly in terms of the butter fat and the solids-not-fat content. If a sample is found to contain less than the prescribed percentage of butter fat or solids-not-fat, it is presumed that the milk is not genuine. In some provinces of India the minimum lactose content as well as the range of specific gravity are also prescribed. The actual standards for cows', buffaloes' and mixed milk prescribed in the various provinces of India (2) have already been described in the section on "Variation in the composition of milk", and reproduced in Table 24 for direct reference. It will be seen that generally speaking the standards are 3·5 per cent butter fat and 8·5 per cent solids-not-fat for cows' milk, 5 to 6 per cent butter fat and 9 per cent solids-not-fat for buffaloe's milk and 3·5 per cent butter fat and 8·5 to 9 per cent solids-not-fat for mixed milk.

TABLE 24

Province or State	Minimum percentage of milk fat	Minimum percentage of solids-not-fat	Minimum percentage of lactose	Specific gravity at 15·5 C.
Cow milk—				
North-West Frontier Province and Ajmer-Merwara	3·5	8·0	..	..
Punjab, United Provinces, Bihar, Bengal, Assam, Bombay Presidency, Sind, Baroda city and Hyderabad (Dn).	3·5	8·5	1·0 (United Provinces) 4·4 (Bengal and Sind).	1·028 to 1·030 in United Provinces and Bengal. Not less than 1·028 in Assam.
Central Provinces, Madras Presidency,* Mysore* and Cochin* States.	3·0	8·5	....	
Buffalo Milk—				
Madras Presidency*, Mysore* and Cochin* States	4·5	9·0	..	..
North-West Frontier Province, Punjab, United Provinces, Ajmer-Merwara and Delhi Province.	..	..	1·0 (United Provinces)	1·028 to 1·030 in United Provinces.
Central Provinces	5·0	8·5	....	....
Bihar, Bengal, Assam, Bombay Presidency, Sind, Baroda city and Hyderabad (Dn.).	6·0	9·0	1·1 (Bengal and Sind)	1·028 to 1·030 in Bengal. Not less than 1·028 in Assam.
Mixed Milk —				
North West Frontier Province, Delhi Province, Ajmer-Merwara and Central Provinces.	3·5		1·0	....
Punjab	3·5	8·6 to 9·0	....	....
Bihar	5·0	9·0	1·0	..

*In Madras Presidency, Cochin and Mysore States, cow milk should have a minimum of 0·5 per cent and buffalo milk 0·53 per cent of nitrogen. Both the milks should not have more than 5 parts of sediment per 100,000 parts of milk on 24 hours standing.

Reproduced from the "Report on the marketing of Milk in India and Burma" 1911.

Considering first the standard for butter fat content of cows' milk it will be noted that the standard prescribed is much lower than what is actually found in the average composition of cows' milk. A corresponding comparison of the legal standard with what is actually found in the average composition of milk of animals in other countries does not show such a large divergence between the two. For example in England and in most European countries the presumptive standard for percentage butter fat is 3 while the actual average percentage butter fat found from the examination of about a million samples of cows' milk is 3·7. The difference is thus only ·7 against the difference of about 1·5 found in India. The result is that adulteration with water or otherwise is possible and is practised on a very wide scale in India.

There is another aspect of the standard for percentage butter fat. Low as the standard is, a certain proportion of genuine samples fails to reach it. It will be seen from Table 2 that the normal range of variation in percentage butter fat in sample of genuine cows' milk is 2·0 to 9·6 and that 5·7 per cent of the samples actually have a percentage of butter fat lower than 3·5. This is, however, inevitable since the idea underlying the standard is to leave the least latitude for adulteration of milk while interfering as little as possible with the sale of the genuine product.

TABLE 25

Percentage of samples of milk falling below the legal limits in England and Wales

Number of samples examined	Percentage of samples falling below 3 per cent fat	Percentage of samples falling below 8·5 per cent solids-not-fat	Authority
676	8·3	24·7	Tocher.
730	8·1	11·6	Cornfield.
127	35·7	10·2	Bailey.
104	7·7	9·6	Monier-William.
6,800	4·9	2·6	Ministry of Agriculture Bulletin.
2,900	3·2	7·8	
11,337 (total)	5·2 (Average)	6·0 (Average)	

Table 25 shows the results of a study made in England and Wales to determine the proportion of genuine samples falling below the minimum limits prescribed under the presumptive standards (28). It will be seen that 5·2 per cent of the samples fall below the prescribed standard. Under the existing standard in India 5·7 per cent of the samples of individual cows' milk fail to pass the legal limit. This would seem to suggest that under our standard a genuine product will be punished about the same number of times as in other countries and that an attempt to enhance the standard will increase the proportion of genuine samples punishable under the law. But this inference is not wholly correct, since milk that is sold is not always the milk of individual animals but is also herd milk whose composition, as we have seen, is less variable than the former. It is therefore important that we should also consider the effect, on sellers of the herd milk, of the existing standards.

It is difficult to state what portion of milk that is sold is herd milk and what portion comes from individual animals. It seems that the number of distributors selling herd milk from several animals is much smaller than the number selling milk of individual animals. For, with the possible exception of 3 or 4 largest cities in India, milk is commonly sold from single animals which are driven from door to door. We guess, however, that the proportion of milk handled in this way, at least in the bigger cities, is smaller than herd milk from more than one animal.

The average size of a herd is not known in India. It is certainly smaller than in Western countries. We feel, however, that to be economic and paying the business should have at least about half a dozen of animals. The special Salvage Committee of the Advisory Board of the Imperial Council of Agricultural Research was not in favour of licensing dealers not dealing with at least 100 to 200 lbs of milk for which about 10 to 20 animals are required. We shall not, however, deal with the question of milk standards on the assumption that milk that is marketed comes from herds of average size, but shall generally deal with the problem of milk standards by setting out the consequences to sellers of milk from herds of all sizes including the individual animals.

TABLE 26

Proportions of sample of milk from herds of different sizes falling below legal limits for butter fat

Butter fat content	Group	Size of herd								
		1*	2	4	6	8	10	12	14	16
					Cows					
Proportion of samples expected to give less than 3·5 per cent.	Red Sindhi	·0431	·0189	·0016	·0002	..	..	..	..	..
	Holstein Sindhi	·1170	·0715	·0191	·0056	·0017	·0005	·0002	..	..
	Village	·0444	·0080	·0003	..	..	..	..	..	..
	All	·0567	·0215	·0021	·0003	..	..	..	..	..
Proportion of samples expected to give less than 4·0 per cent.	Red Sindhi	·1587	·0886	·0283	·0097	·0035	·0013	·0005	·0002	·0001
	Holstein Sindhi	·3509	·2517	·1721	·1232	·0904	·0673	·0506	·0375	·0292
	Village	·0914	·0327	·0046	·0007	·0001	..	..	..	..
	All	·1803	·0911	·0296	·0104	·0038	·0015	·0005	·0002	·0001
					Buffaloes					
Proportion of samples expected to give less than 5·5 per cent.	Murrah	·0674	·0439	·0079	·0016	·0003	·0001	..	..	..
	Village	·0897	·0302	·0039	·0006	·0001	..	..	..	..
	All	·0780	·0363	·0056	·0009	·0002	..	..	..	..
Proportion of samples expected to give less than 6·0 per cent.	Murrah	·1623	·1163	·0457	·0194	·0085	·0038	·0017	·0008	·0004
	Village	·1573	·0756	·0211	·0064	·0020	·0007	·0002	·0001	..
	All	·1592	·0912	·0296	·0104	·0038	·0014	·0005	·0002	·0001

* Proportions given for herds of size 1 are those actually observed.

Table 26 shows the proportion of samples of cows' milk from herds of different sizes expected to give less than 3·5 and 4 per cent of butter fat content. These proportions are easily calculated knowing the standard deviation and the form of the frequency distribution of the percentage butter fat.

It has been assumed that the frequency distributions are of the normal form. The assumption is not strictly valid especially for the percentage of butter fat and the specific gravity but it can be shown that it does not introduce any material error in the actual figures for the proportion of samples falling below the legal limits and those expected on normal theory. It will be seen that the proportions diminish rapidly with the size of the herd. For herds of half a dozen animals the proportions are of the order of 2 in 10 thousand samples of village cows and only 3 in 10 thousand in all cows even including the Holstein Sindhi group which forms but only a negligible proportion of the cattle in India. With a herd of 15 animals that the Salvage Committee is aiming at it will be seen that dairy farmers will almost invariably produce milk of the requisite standard and that hardly one in a million of genuine samples will be punished under the law.

The position is much the same with regard to the standard for percentage butter fat in buffaloes' milk. The existing standard is 5·5 in most provinces in India, while the actual average value is much larger. The proportion of genuine samples of milk from herds of different sizes falling below the standard prescribed is shown in Table 26. It will be seen that the proportion of samples of milk from herds of 6 or more buffaloes failing to pass the legal standard is negligible.

It will be obvious from the foregoing discussion that the existing standards for percentage butter fat in cows' and buffaloes' milk are too low to be of any value and that they must be revised to put a check on legalised adulteration. The data, we have, relate to comparatively restricted areas. We are not able, therefore, to discuss in this report what the standards should be in the different provinces. The standards may well vary from province to province depending upon the regional climate, breed of animals and feeding standards. We shall merely set out, as in Table 26, the consequences of reducing the latitude for adulteration by 5, thus increasing the standard to 4 per cent of butter fat in the case of cows' milk and to 6 per cent of butter fat in the case of buffaloes' milk. It will be seen that the proportions of samples falling below these limits will be only one in hundred in milk of herds of 6 animals and will be of the order of one in ten thousand in herds of 15 animals. Compared with other countries even these may well be considered to be somewhat too low, but clearly other factors including the variation in climate from region to region, the representative character of the data and the practice of mixing the buffaloes' milk with the cows' milk must partly determine the limits.

Turning to the standards for percentage solids-not-fat, it will be seen from Table 24 that the standards are 8·5 for cows' milk and 9 for buffaloes' milk. A comparison of these legal limits with the values actually found in the average composition of milk shows that the difference between the two is much narrower than what is found in the case of percentage butter fat. The actual average value for percentage solids-not-fat in cows' milk at Allahabad is found to be 8·45 and for the Allahabad and other data reported to us put together is 8·69. Compared to the former the standard will be seen to be slightly higher but compared to the latter it is seen to be lower by about 0·2. The average value for percentage solids-not-fat found in the composition of buffaloes' milk is 9·3 and leaves a latitude of 0·3 between itself and the legal limit. Table 27 shows the proportions of samples of milk from herds of different sizes expected to fall below the legal standards. It will be seen from the table that more than half the number of samples of milk of individual cows and 23 per cent of the samples of milk of individual buffaloes fall below the prescribed standard. It will also be seen that the proportion of samples falling below the prescribed standard for cows' milk does not decrease with the size of herd. This is expected, since the standard prescribed is higher than the actual average of percentage solids-not-fat found in the milk. For herds of buffaloes the proportions diminish with size. The proportion is seen to be 12 per cent for herds of 6 animals and about 3 per cent for herds of 15. It will be noted that the proportions are larger than the corresponding values in the case of percentage butter fat. It means that there is greater chance of a genuine product falling below the prescribed standard for percentage solids-not-fat than of its falling below the standard for percentage butter fat. We do not, however, know if in actual practice this is so. We suspect not. For if the percentage solids-not-fat is determined by Richmonds' formula, then as will be shown later, the sample may appear richer in solids-not-fat than what it actually is and consequently the chance of its being punished under the standard may be greatly diminished. On the other hand if the solids-not-fat content is determined by the laboratory method the proportion of samples punishable under the law is likely to be heavy. With Richmond's scale inapplicable under Indian conditions it seems advisable that the standard for the percentage solids-not-fat, at least in cows' milk, should be lowered.

TABLE 27

Proportions of samples of milk from herds of different sizes falling below legal limits for solids-not-fat

Proportion of samples expected to give less than.	Group	Size of herd								
		1*	2	4	6	8	10	12	14	16
Solids-not-fat—					*Cows*					
8·0 per cent	Red Sindhi	·1331	·0931	·0309	·0110	·0041	·0015	·0006	·0002	..
	Holstein Sindhi	·4386	·3978	·3568	·3267	·3022	·2810	·2627	·2463	·2317
	Village	·1344	·0804	·0236	·0075	·0026	·0009	·0002	·0001	..
	All	·1888	·1335	·0587	·0276	·0134	·0067	·0031	·0017	·0009
8·5 per cent	Red Sindhi	·4898	·5032	·5044	·5056	·5064	·5072	·5076	·5084	·5088
	Holstein Sindhi	·8889	·9164	·9746	·9916	·9971	·9990	·9996	·9999	1·0000
	Village	·3441	·3435	·2840	·2423	·2098	·1835	·1616	·1428	·1269
	All	·5334	·5382	·5541	·5663	·5761	·5851	·5933	·6003	·6072
					Buffaloes					
8·5 per cent	Murrah	·0828	·0641	·0158	·0042	·0012	·0003	·0000	..	..
	Village	·0554	·0233	·0025	·0003	..	..	..	..	..
	All	·0659	·0395	·0065	·0012	·0002	..	..	..	..
9·0 per cent	Murrah	·2825	·3238	·2588	·2142	·1805	·1534	·1314	·1131	·0980
	Village	·1915	·1932	·1103	·0668	·0415	·0263	·0169	·0110	·0071
	All	·2264	·2160	·1658	·1192	·0849	·0623	·0463	·0346	·0261

* Proportions given for herds of size 1 are those actually observed.

Though it is mainly the percentage butter fat and the percentage solids-not-fat which determine the quality of milk standards for specific gravity and percentage lactose have also been prescribed in some provinces of India. Tables 28 and 29 show the proportions of samples of cows' and buffaloes' milk falling below the existing standards for specific gravity and lactose content. It will be seen that in a herd of size 6 or more, the proportion of samples falling below the prescribed standard of 1·028 for specific gravity is only 9 in ten thousand. The proportion is seen to be almost negligible for a herd of size 15. For buffaloes the proportions are even smaller. This is, however, expected, since buffaloes' milk is heavier than cows. In regard to lactose it will be seen that the standard of 4 per cent is adequate for cows' milk but is a bit too low for buffaloes' milk. For the latter 4·4 per cent appears to be more adequate.

TABLE 28

Proportion of samples of milk from herds of different sizes falling below legal limits for specific gravity

Proportion of samples expected to give less than :	Group	Size of herd								
		1*	2	4	6	8	10	12	14	16
					Cows					
Specific Gravity 1·028*	Red Sindhi	·0768	·01	·001	·0001	..				
	Holstein Sindhi	·1228	·0715	·0206	·0062	·0020	·0006	·0002	..	
	Village	·1022	·0583	·0132	·0033	·00097	·0002	0001	·0001	
	All	·0901	·0359	·0055	·0009	·00027				
					Buffaloes					
1·028 *	Murrah	·0844	·0434	·0077	·0015	·0003	·0006			
	Village	·0565	·0188	·0016	·0002	..	..			
	All	·0672	·0203	·0019	·000					

*Proportions given for herds of size 1 are those actually observed

TABLE 29

Proportion of samples of milk from herds of different sizes falling below the legal limits for lactose

Proportion of samples expected to give less than :	Group	Size of herd								
		1*	2	4	6	8	10	12	14	16
					Cows					
Lactose—										
4·0 per cent	Red Sindhi	·0990	·0357	·0054	·0009	·0002	..	..	..	..
	Holstein Sindhi	·1404	·0908	·0295	·0103	·0038	·0014	·0005	·0002	·0001
	Village	·0806	·0240	·0026	·0003	..	..	..	..	..
	All	·1029	·0439	·0079	·0016	·0003	·0001	..	..	..
4·4 per cent	Red Sindhi	·2526	·2850	·2119	·1626	·1280	·1020	·0823	·0664	·0540
	Holstein Sindhi	·4503	·5096	·5136	·5164	·5191	·5211	·5231	·5251	·5267
	Village	·1452	·1658	·0847	·0463	·0260	·0150	·0087	·0051	·0030
	All	·2672	·2918	·2192	·1713	·1368	·1103	·0898	·0737	·0607
					Buffaloes					
4·0 per cent	Murrah	·0649	·0163	·0012	·0001	..	..	..	..	..
	Village	·0323	·0011	..	..	..	..	..	..	..
	All	·0448	·0043	·0001	..	..	..	..	..	..
4·4 per cent	Murrah	·1526	·1397	·0631	·0305	·0153	·0078	·0044	·0021	·0011
	Village	·1169	·0410	·0069	·0013	·0003	·0001	..	..	..
	All	·1306	·0761	·0214	·0066	·0021	·0007	·0002	·0001	..

*Proportions given for herds of size 1 are those actually observed.

In addition to butter fat, solids-not-fat, specific gravity and lactose, freezing point as a test for detecting adulteration in milk has been considered of some importance but in India no standard for this character is prescribed. We have not enough data to substantiate the claim that the freezing point can be used as a reliable test of added water but in view of the close relationship between the freezing point of milk and the added double distilled water to which reference will be found in the next section, we suggest that the possibility of prescribing standard for freezing point may be considered.

Besides cows' and buffaloes' milk standards are also prescribed for mixed milk of cows and buffaloes. Our data are too limited to offer any comments on this complicated question of fixing standards for the mixed milk.

6. CORRELATIONS BETWEEN THE VARIOUS CHARACTERS OF MILK

The object of this section is to discuss the correlations between the milk yield, the specific gravity and the percentage content of major constituents like the butter fat, solids-not fat, moisture, lactose, ash and crude protein. It is also proposed to note the correlation of freezing point depression with some of the above factors, and discuss a few other correlations of interest.

It will occupy too large a portion of the report if all the correlation tables proposed to be discussed were given. We have thought it sufficient to give what may be described ' the regression tables ' which show the average values of the dependent factors for ascending values of the independent ones. We have also given diagrams which help to read the type and to some extent the intensity of association between the factors. A table is also given showing the values for each of the several pairs of factors, of a measure of intensity known as the coefficient of correlation (Table 30). Values of the correlation coefficient which cannot be considered as having arisen through chance or sampling error are marked with asterisks in the table.

TABLE 30

Correlation Coefficients

		Cows		Buffaloes		
		Red Sindhi	Holstein-Sindhi	Village	Murrah	Village
Milk Yield	Specific Gravity	·28*	·37*	·00	·40*	·39*
	Percentage Butter Fat	—·47*	—·52*	—·34*	—·43*	—·44*
	,, Solids-not-fat	·13*	·13	—·13	·09	·09
	,, Lactose	·55*	·64*	—09·	·40*	·36*
	,, Ash	—·37*	—·41*	·13	·09	·04
	,, Crude Protein	—·46*	—·56*	—·16†	—·25*	—·17*
Specific Gravity	Percentage Butter Fat	—·19*	—·35*	—·17†	—·27*	—·53*
	,, Solids-not-fat	·67*	·24*	·80*	·64*	·61*
	,, Lactose	·60*	·42*	·61*	·64*	·54*
	,, Ash	·01	—·10	—·06	·25*	·38*
	,, Crude Protein	·17*	—·13	·37*	·18†	·26*
Percentage Butter Fat	Percentage Solids-not-fat	·19*	—·06	·07	·09	—·06
	,, Lactose	—·26*	—·44*	·09	—·18†	—·38*
	,, Ash	·41*	·40*	—·05	·13†	·06
	,, Crude Protein	·57*	·54*	·21*	·46*	·34*
	,, Casein	·56*	·42*	·47*	·57*	·34*
Percentage Solids-not-fat	Percentage Lactose	·46*	·15	·67*	·43*	·31*
	,, Ash	·25*	·10	—·11	·36*	·52*
	,, Crude Protein	·47*	·19†	·60*	·55*	·57*
Percentage Lactose	Percentage Ash	—·34*	—·38*	—·38*	—·16†	·06
	,, Crude Protein	—·29	—·56*	·16†	—·23*	—·25*
	,, Chlorine	—·61*	·66*	—·61*	—·46*	—·53*
Percentage Ash	Percentage Crude Protein	·63*	·48*	·18†	·56*	·58*
Percentage Crude Protein	Percentage Casein	·90	·86	·90	·88	·89
Percentage Total Solids	Specific gravity	·16*	—·21†	·25*	·04	—·26*
	Percentage Butter Fat	·87*	·84*	·86*	·89*	·92*
	,, Solids-not fat	·58*	·38*	·54*	·51*	·31*
	,, Lactose	·01	—·31*	·40*	·03	—·23*
	,, Ash	·44*	·40*	—·08	·26*	·25*
	,, Crude protein	·68*	·60*	·50*	·62*	·54*
Freezing Point depression	Specific Gravity	·20	..	..	..	·07
	Percentage Butter Fat	·00	..	..	..	·03
	,, Solids-not fat	·20	..	..	..	·07
	,, Total Solids	·14	..	..	..	·07
	,, Lactose	·11	..	..	..	·18
	,, Ash	—·05	..	..	..	—·11
	,, Crude Protein	·15	..	..	..	—·05
	,, Chlorine	·26	..	..	..	—·13

* Indicates significance at 1 per cent level of probability.
† Indicates significance at 5 per cent level of probability.

Yield and other factors.—Tables 31 and 32 show the average values of the various factors for values of the milk yield increasing by equal intervals. Column 2 of the tables gives the number of samples and helps to show how far the array averages are reliable. Diagrams 1 and 2 help to show the type and the degree of relationship between the milk yield and other factors. It will be noticed that the end portions of the lines, particularly those relating to Holstein Sindhi and Sindhi groups, show rather violent fluctuations owing to the very small number of samples on which the end averages are based.

TABLE 31

Mean values of specific gravity, percentage butter fat, solids cows not fat, lactose, ash and crude cows

Milk yield in oz.	Red Sindhi							Holstein		
	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	No. of samples	Specific gravity	Percentage butter fat
8·5	12	1·02838	5·338	8·088	4·022	0·7838	3·538	1	1·02955	5·005
24·5	32	1·02843	5·668	8·036	3·774	0·7905	3·474	2	1·02655	5·005
40·5	26	1·02993	5·826	8·367	4·051	0·8297	3·567	3	1·02755	4·472
56·5	36	1·03033	5·616	8·472	4·238	0·7816	3·438	2	1·03055	6·405
72·5	26	1·03070	5·390	8·605	4·428	0·7774	3·497	2	1·02755	5·805
88·5	30	1·03085	5·472	8·652	4·552	0·7685	3·425	4	1·02880	5·305
104·5	30	1·03078	5·152	8·478	4·558	0·7618	3·305	6	1·02822	5·528
120·5	40	1·03080	5·345	8·555	4·535	0·7595	3·315	12	1·02838	5·405
136·5	28	1·03055	4·876	8·348	4·448	0·7619	3·176	5	1·02835	5·325
152·5	28	1·03155	5·048	8·476	4·648	0·7548	3·269	7	1·02912	4·605
168·5	31	1·03145	4·837	8·628	4·726	0·7624	3·240	5	1·02975	4·605
184·5	34	1·03143	4·619	8·587	4·793	0·7381	3·123	3	1·02888	4·872
200·5	29	1·03152	4·564	8·546	4·705	0·7405	3·105	3	1·02988	4·072
216·5	22	1·03114	4·460	8·550	4·814	0·7223	2·950	5	1·02975	4·685
232·5	34	1·03137	4·487	8·511	4·846	0·7276	2·940	3	1·02955	4·605
248·5	24	1·03126	4·572	8·472	4·830	0·7305	3·005	5	1·02955	4·365
264·5	26	1·03159	4·297	8·636	4·905	0·7159	2·967	9	1·02899	3·938
280·5	22	1·03150	4·223	8·532	4·805	0·7150	2·941	9	1·03033	3·983
296·5	13	1·03201	4·082	8·567	4·905	0·6974	2·982	6	1·03055	3·738
312·5	18	1·03138	4·538	8·516	4·883	0·6938	3·005	5	1·02975	4·365
328·5	12	1·03113	4·505	8·705	4·805	0·7372	3·072	4	1·03080	4·105
344·5	4	1·03205	4·505	8·605	4·855	0·7705	3·055	6	1·02988	4·538
360·5	9	1·03122	4·383	8·505	4·749	0·7272	2·972	8	1·03005	3·855
376·5	5	1·03155	4·365	8·945	4·705	0·7245	3·265	4	1·02930	4·405
392·5	5	1·03095	4·445	8·425	4·865	0·7005	2·905	5	1·02995	4·125
408·5	2	1·03155	4·605	8·605	5·305	0·6405	3·105	5	1·02995	4·525
424·5	1	1·03155	4·205	8·905	4·905	0·8205	3·105	4	1·02930	3·305
440·5	..	..	..	..	..	..	..	8	1·02980	4·105
456·5	2	1·03155	3·605	8·605	5·605	0·6805	2·905	2	1·02955	4·005
472·5	1	1·03055	4·205	8·305	4·705	0·8205	2·705	1	1·02955	5·805
488·5	..	..	..	..	..	..	..	6	1·02972	3·938
504·5	..	..	..	..	..	..	..	7	1·03026	3·748
520·5	1	1·02955	3·805	8·105	4·705	0·7405	2·905	4	1·03030	4·005
536·5	..	..	..	..	..	..	..	3	1·02988	3·805
552·5	1	1·02855	5·005	8·305	4·905	0·7005	2·705	4	1·02980	3·705
568·5	1	1·02855	4·205	8·105	5·105	0·7405	2·705	..	..	..
584·5	..	..	..	..	..	..	..	2	1·03005	3·805
600·5	..	..	..	..	..	..	..	1	1·03055	3·805
616·5	1	1·2955	3·405	8·305	4·705	0·7405	2·705			
Total .	586	..	..	..	..	..	..	171	..	..
Coefficient of Correlation.	..	0·28*	—0·47*	0·13*	0·55*	—0·37*	—0·46*	..	0·37*	—0·52*

TABLE 31—*contd.*

protein for values of daily milk yield increasing at equal intervals

Sindhi				Village						
Percentage solids-not-fat	Percentags lactose	Percentage ash.	Percentage crude protein	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein
7·705	4·505	0·8205	4·305	8	1·02955	6·005	8·155	4·580	0·7155	3·080
8·005	3·605	0·7205	3·305	43	1·03067	6·121	8·617	4·714	0·7210	3·334
7·905	3·305	0·7405	3·572	52	1·03111	5·520	8·847	4·836	0·7051	3·349
7·905.	3·405	0·8205	3·505	26	1·03128	5·774	8·728	4·759	0·7436	3·336
7·805	3·805	0·7805	3·105	30	1·03218	5·432	9·038	5·018	0·7378	3·485
7·955	4·055	0·7505	3·155	8	1·03180	5·705	8·880	5·055	0·7455	3·255
8·038	3·938	0·8138	3·372	3	1·02822	5·272	8·105	4·638	0·7272	2·705
8·105	4·138	0·7772	3·222	3	1·02922	5·272	7·838	4·238	0·7405	3·038
8·105	4·105	0·7565	3·145	..	..	..	..	..	..	..
8·076	4·134	0·7405	3·134	4	1·02980	4·305	7·855	4·705	0·7505	2·905
8·265	4·225	0·7405	3·145	2	1·03105	4·205	8·405	4·305	0·7605	3·405
7·905	4·238	0·7805	3·238	1	1·03155	3·805	8·305	4·305	0·7005	3·105
7·972	4·105	0·7672	3·105	2	1·02955	3·605	7·805	4·105	0·7205	2·805
8·185	4·305	0·7405	3·105	..	..	..	..	..	..	..
7·838	4·305	0·7138	2·705	4	1·03080	4·405	8·405	4·505	0·7405	3·055
7·825	4·345	0·7325	2·825							
7·816	4·327	0·7094	2·749							
8·127	4·638	0·7183	2·772							
8·138	4·705	0·7138	2·772							
8·305	4·545	0·7405	2·825							
7·955	4·705	0·7505	2·905							
7·972	4·705	0·6872	2·705							
8·255	4·605	0·7105	2·830							
8·005	4·555	0·7205	2·805							
7·985	4·305	0·7085	3·185							
8·465	4·745	0·7325	2·785							
7·855	4·655	0·7205	2·555							
8·105	4·530	0·7305	2·755							
9·105	4·605	0·6605	2·705							
8·905	4·905	0·7405	3·305							
8·038	4·538	0·7138	2·672							
8·191	4·676	0·7291	2·762							
8·205	4·655	0·7305	2·755							
7·838	4·638	0·7005	2·505							
8·005	4·655	0·7205	2·555							
..	..	..	..							
8·305	4·805	0·7005	2·705							
8·105	5·105	0·7405	2·705							
..	..	..	..	186	..	..	..	..	..	..
0·13	0·64*	—0·41*	—0·56*	..	0·00	—0·31*	—0·13	—0·09	0·13	—0·16

TABLE 32

Mean values of specific gravity, percentage butter fat, solids-not-fat, lactose, ash and crude protein for values of daily milk yield increasing at equal intervals

BUFFALOES

Milk yield in oz.	Murrah							Village						
	No. of Samples.	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash.	Percentage crude protein	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude-protein
8·5	3	1·02888	9·805	9·905	3·338	0·8738	5·372	3	1·02955	9·272	8·868	4·305	0·8205	4·238
24·5	6	1·02605	7·672	8·172	3·405	0·8738	3·972	16	1·02867	9·905	9·372	4·080	0·8155	4·143
40·5	10	1·02815	8·885	8·945	4·085	0·8165	4·085	20	1·02980	9·325	9·305	4·745	0·7945	4·015
56·5	6	1·02938	8·872	9·072	4·672	0·7472	4·005	46	1·03072	8·614	9·427	4·757	0·7831	3·962
72·5	11	1·02991	7·950	8·850	4·378	0·7223	3·850	50	1·03021	8·429	9·325	4·769	0·7797	3·841
88·5	21	1·03026	8·110	9·095	4·619	0·7500	3·800	47	1·03129	7·652	9·314	4·939	0·7550	3·701
104·5	30	1·03085	7·178	9·318	4·912	0·7378	3·702	54	1·03168	7·205	9·483	4·916	0·8020	3·827
120·5	19	1·03071	7·594	9·284	4·726	0·7468	3·979	60	1·03197	7·272	9·358	5·048	0·7912	3·708
136·5	12	1·03013	7·472	9·305	4·872	0·7505	3·722	47	1·03197	7·286	9·453	4·994	0·8001	3·782
152·5	38	1·03176	7·131	9·421	4·905	0·7531	3·794	53	1·03244	7·035	9·753	5·120	0·7948	3·720
168·5	17	1·03096	7·076	8·976	4·846	0·7735	3·728	40	1·03205	7·095	9·240	5·045	0·7855	3·685
184·5	23	1·03238	6·866	9·479	4·914	0·7544	3·827	24	1·03293	6·888	9·497	5·063	0·7822	3·697
200·5	25	1·03139	6·573	9·169	4·865	0·7549	3·665	10	1·03185	6·605	9·325	5·125	0·7885	3·425
216·5	21	1·03231	6·643	9·210	5·076	0·7576	3·572	6	1·03322	6·872	9·505	5·171	0·7672	3·638
232·5	19	1·03260	6·626	9·305	5·042	0·7805	3·610	6	1·03438	7·005	9·672	5·139	0·8205	4·205
248·5	16	1·03211	6·580	9·155	5·105	0·7805	3·518	4	1·03305	7·105	9·255	4·905	0·8705	3·505
264·5	4	1·02955	6·005	8·405	4·655	0·7105	3·305	3	1·03422	6·338	9·838	5·105	0·8205	4·238
280·5	7	1·03169	6·434	9·134	5·048	0·7919	3·448	3	1·03222	6·738	9·438	5·172	0·7538	3·572
296·5	7	1·03269	6·662	9·334	4·905	0·8034	3·705	..	..	..	..	..	..	..
312·5	3	1·03488	5·538	9·772	4·972	0·8605	4·038	2	1·03253	5·805	9·305	4·805	0·7805	3·605
328·5	4	1·03280	6·105	9·305	5·055	0·8205	3·705							
344·5	1	1·03450	7·005	9·705	4·905	0·8605	4·305							
360·5	1	1·03250	7·805	8·905	5·105	0·8205	3·905							
376·5	1	1·03550	6·605	10·105	4·905	0·8605	4·305							
392·5	..	..	..	..	..	..	..							
408·5	1	1·03350	6·605	9·305	4·905	0·8605	3·905							
424·5	..	..	..	..	..	..	..							
440·5	..	..	..	..	..	..	..							
456·5	2	1·03150	6·005	8·905	5·005	0·8205	3·405							
Total	308	..	..	..	..	..	..	494	..	..	..	..	..	..
Coefficient of correlation.	..	0·40*	−0·43*	0·09	0·40*	0·09	−0·25*	..	0·30*	−0·44*	0·09	0·36*	0·04	−0·17*

It will be seen from Diagrams (1·1) and (2·1) that excepting in village cows there is a general tendency for the specific gravity to increase with the milk yield, but the rate of increase diminishes as the milk yield increases. In other words the figures suggest a parabolic relationship between the specific gravity and the milk yield. The relationship is fairly close, but is closer in buffaloes than in cows. For a non-linear relationship, such as is observed between the specific gravity and the milk yield, the coefficient of correlation is not the best measure of the intensity of association, but it can serve to give some idea of the intensity. It will be seen from Table 30 that the coefficient of correlation is zero in village cows and varies from 0·28 in the Red Sindhi group to 0·40 in the Murrah group .

Diagrams (1·2) and (2·2) suggest a high negative correlation between the percentage butter fat and the milk yield. There is a suggestion that the relationship is slightly non-linear. It will be observed that the rate of decrease in the percentage of butter fat with the increase in milk yield is a little more rapid for low levels of milk yield than for high levels. The relationship is of about equal intensity in cows and in buffaloes. The values of the coefficients of correlation vary from—0·34 in village cows to —0·52 in Holstein Sindhi cows. Since as will be observed later the butter fat content and the milk yield are largely influenced by time, part of this relationship is spurious due to time factor.

Diagrams (1·3) and (2·3) do not suggest any association between the percentage of solids-not-fat and the milk yield. The values of the coefficients of correlation shown in Table 30 confirm this conclusion. It will be seen that the correlations are small and that all except one are non-significant.

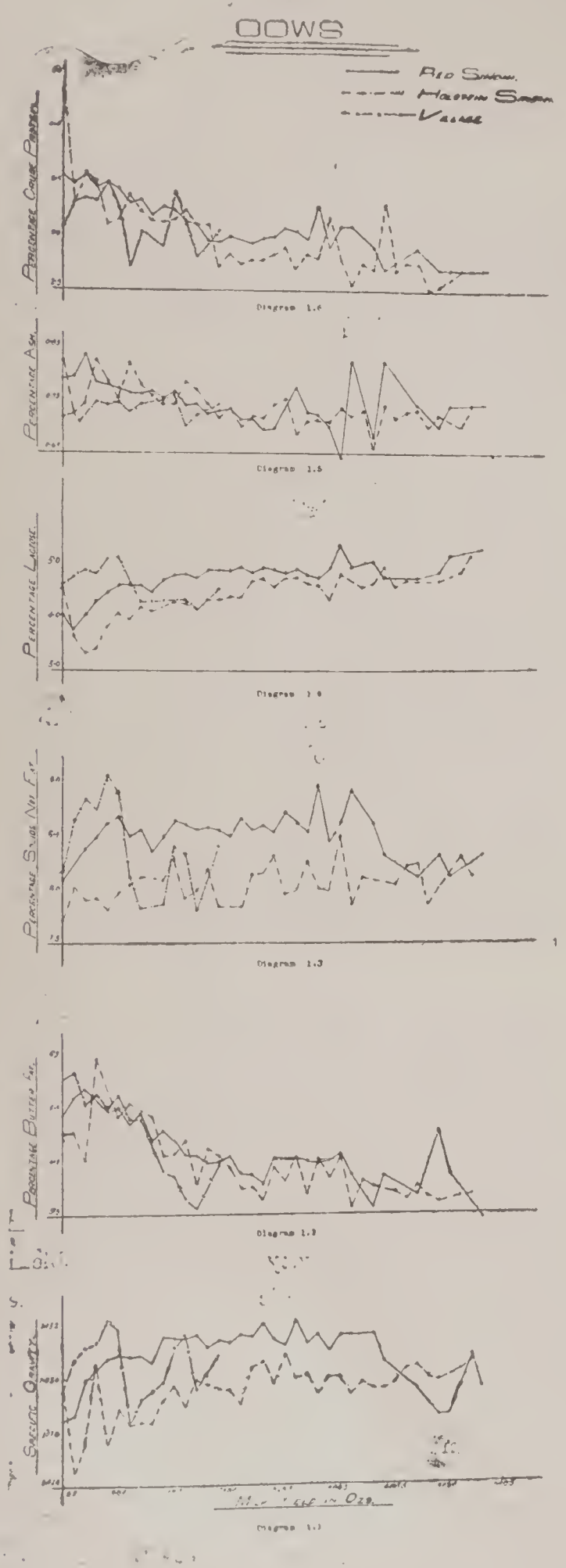
Diagrams (1·4) and (2·4) suggest a high positive association between the percentage of lactose and the milk yield in all except the village cows. The relationship appears to be parabolic in character. The correlations are 0·40 in Murrahs and 0·36 in village buffaloes and 0·55 in Red Sindhis and 0·64 in Holstein Sindhi cows. The correlation as already observed is small and non-significant in the village cows.

Diagrams (1·5) and (2·5) suggest a negative relationship between the ash content and the milk yield in the Red Sindhi and the Holstein Sindhi groups of cows but in the village group of cows and in both the groups of buffaloes, there is no evidence of relationship between the two. The relationship may be regarded as linear. The coefficient of correlation has a value of —0·37 in the Red Sindhi and —0·41 in the Holstein Sindhi group. For other groups the correlation coefficients are small and not significant.

Crude protein shows a negative relationship with the milk yield. The relationship is linear in type. Diagrams (1·6) and (2·6) show that the relationship is less close in the village cows and buffaloes than in the Red Sindhi and Holstein Sindhi cows. Possibly the low association in village cows and village buffaloes is due to the small range of values for milk yield, as compared with the range obtained in the Red Sindhi, Holstein Sindhi and Murrah groups. The coefficient of correlation is of the order of —0·16 in village cows and buffaloes ; for the Murrah group the correlation is —0·25 ; and for the Red Sindhi and Holstein Sindhi groups the correlations are —0·46 and —0·56 respectively.

Specific Gravity and Other Factors.

Tables 33 and 34 and Diagrams 3 and 4 show the mean values of the percentage butter fat, solids-not-fat lactose, ash and crude protein for ascending values of the specific gravity. The irregular and erratic behaviour of various factors at the extreme values of the specific gravity is again noticeable in the diagrams. A reliable picture of the association can only be read from the middle portions of the diagrams lying within the range, say 1·02555 to 1·03455 for Red Sindhi cows, 1·02655 to 1·03155 for Holstein Sindhi cows, 1·02655 to 1·03555 for village cows, 1·02555 to 1·03555 for Murrah buffaloes and 1·02655 to 1·03755 for village buffaloes.


OOWS
Red Salmon.
Humpback Salmon
Average
Percentage Cover Portion
Percentage Ash
Percentage Lactose
Percentage Solids Not Fat
Percentage Butter Fat
Specific Gravity
Diagram 1.6
Diagram 1.5
Diagram 1.4
Diagram 1.3
Diagram 1.2
Diagram 1.1

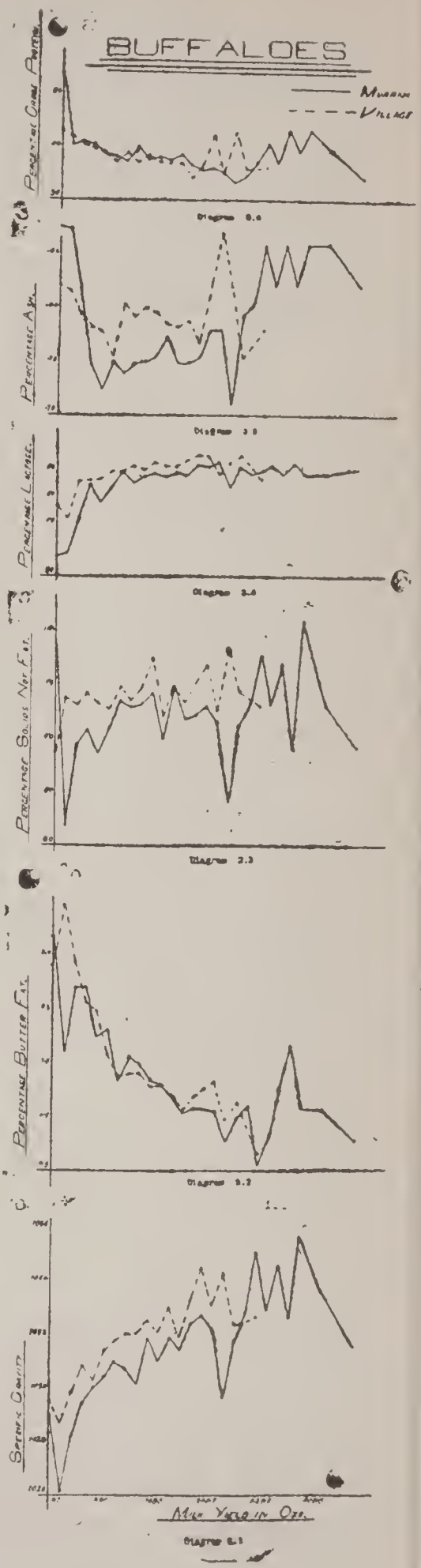

BUFFALOES
Percentage Cover Portion
Percentage Ash
Percentage Lactose
Percentage Solids Not Fat
Percentage Butter Fat
Specific Gravity
Diagram 2.6
Diagram 2.5
Diagram 2.4
Diagram 2.3
Diagram 2.2
Diagram 2.1

TABLE 33

Mean values of percentage butter fat, solids-not-fat, lactose, ash and crude protein for values of specific gravity increasing at equal intervals

Cows

Values of specific gravity	Red Sindhi						Holstein Sindhi						Village					
	No. of samples	Percentage butter-fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	No. of samples	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	No. of samples	Percentage butter fat	Percentage solds-not-fat	Percentage lactose	Percentage ash	Percentage crude protein
1·01955													1	7·005	8·505	4·905	0·6605	3·105
1·02055							1	4·605	8·305	4·105	0·7805	3·505	..	..	..	..	..	..
1·02155	1	3·005	5·905	2·105	0·7805	2·905	..	..	..	.	..	..	2	4·405	6·205	2·205	0·9405	2·705
1·02255	1	3·405	6·105	2·705	0·6605	2·905	..	..	..	..	.	..	2	5·205	6·605	3·005	0·8205	3·305
1·02355	1	6·605	7·305	3·305	0·7805	3·505	..	.	..	..	.	..	1	8·205	7·705	3·905	0·6205	3·305
1·02455	3	4·605	7·038	3·572	0·6338	2·838	..	..	..	..	..	..	1	3·405	6·505	2·505	0·8205	3·505
1·02555	11	5·514	7·450	3·614	0·7732	3·178	2	6·005	7·405	3·705	0·7205	3·005	2	5·805	7·705	4·505	0·7405	3·405
1·02655	9	5·361	7·661	3·772	0·7449	3·149	7	5·062	7·562	3·705	0·7405	2·962	3	6·072	7·638	4·705	0·6338	3·238
1·02755	19	5·679	8·052	4·063	0 7905	3·337	11	5·514	7·941	4·032	0 7441	3·141	7	5·805	7·991	4·219	0·7405	3·048
1·02855	32	5·543	8·080	4·149	0·7693	3·230	27	4·664	8·024	4·320	0·7390	2·964	12	5 472	8·138	4·505	0·7105	2·988
1·02955	66	5·017	8·281	4·490	0·7411	3·093	63	4·307	8·140	4·438	0·7380	2·921	24	5·988	8·388	4·747	0·7068	3·105
1·03055	131	4·923	8·436	4·624	0·7408	3·100	44	3·996	8·105	4·569	0·7250	2·801	27	5·909	8·586	4·794	0·7082	3·216
1·03155	167	4·823	8·598	4·739	0·7451	3·186	14	4·348	8·291	4·562	0·6405	3·134	33	5·878	8·808	4·917	0·7138	3·293
1·03255	100	4·729	8·787	4·749	0·7613	3·323	2	4·605	8·005	4·105	0·7405	2·905	30	5·725	9·012	4·972	0·7392	3·438
1·03355	37	4·681	8·937	4·743	0·7686	3·456							25	4·941	9·217	5·081	0·7293	3·462
1·03455	7	4·719	9·391	4·991	0·7805	3·648							9	4·605	9·349	5·016	0·7272	3·549
1·03555	1	4·605	9·505	5·105	0·7405	3·905							6	5·072	9·905	5·238	0·7405	4·072
1·03655													1	4·205	10·105	5·105	0·7805	4·305
Total .	586						171						186					
Coefficient of correlation		—0·19*	0·67*	0·60*	0·01	0·17*		—0·35*	0·24*	0·42*	—0·10	—0·13		—0·17*	0·80*	0·61*	—0·06	0·37*

TABLE 34

Mean values of percentage butter fat, solids-not-fat, lactose, ash and crude protein for values of specific gravity increasing at equal intervals

BUFFALOES

Values of specific gravity	Murrah						Village					
	No. of samples.	Percentage butter fat.	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	No. of samples	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein
1·01855	1	4·205	5·705	3·105	0·4605	2·305						
1·01955	1	8·205	8·505	2·505	0·8205	3·705						
1·02055	1	3·805	5·505	1·505	1·0605	3·305						
1·02155	1	3·805	6·305	3·105	0·5805	2·905	1	5·805	6·105	3·105	0·5005	2·505
1·02255	3	9·005	8·638	3·038	0·8338	4·705	3	8·072	7·305	3·505	0·6472	3·238
1·02355	..	..	..	..	..	..	3	6·072	7·572	3·705	0·5938	2·905
1·02455	1	5·805	7·305	4·105	0·5805	2·905	1	8·605	7·305	5·565	0·7005	3·505
1·02555	5	7·485	7·985	3·545	0·8045	3·745	4	10·705	8·655	4·005	0·8105	4·105
1·02655	4	7·405	8·255	4·505	0·7805	3·305	2	12·005	8·705	3·405	0·8805	5·105
1·02755	9	7·673	8·483	4·327	0·7138	3·572	14	10·462	9·048	4·405	0·8148	3·976
1·02855	20	7·945	9·025	4·465	0·7505	3·785	26	8·867	9·044	4·682	0·7636	3·605
1·02955	29	7·929	9·160	4·781	0·7391	3·815	62	8·192	9·186	4·786	0·7586	3·657
1·03055	45	7·581	8·905	4·732	0·7529	3·603	89	8·223	9·238	4·894	0·7706	3·521
1·03155	72	6·981	8·788	4·988	0·7633	3·636	80	7·760	9·415	5·033	0·7810	3·740
1·03255	59	6·897	9·342	5·091	0·7561	3·736	87	7·331	9·427	5·038	0·7938	3·717
1·03355	24	6·373	11·263	4·997	0·7838	3·872	55	6·627	9·661	5·138	0·8009	3·796
1·03455	21	6·701	9·743	4·972	0·9748	3·934	45	6·161	9·723	5·145	0·8338	3·901
1·03555	7	6·489	10·105	5·019	0·8891	4·448	9	6·161	10·216	4·972	0·8649	4·549
1·03655	3	6·605	9·905	4·705	0·9005	4·238	9	5·494	10·483	5·083	0·9183	4·549
1·03755	1	5·405	10·905	3·905	0·8605	5·305	3	6·605	10·438	4·972	0·9005	4·772
1·03855	1	6·605	9·105	5·105	0·7005	3·305	3	5·272	10·735	5·105	0·9272	5·172
Total	308						496					
Coefficient of correlation		—0·27*	0·64*	0·64*	0·25*	0·18*		—0·53*	0·61*	0·54*	0·38*	0·26*

Diagrams (3·1) and (4·1) show a tendency for the percentage butter fat to generally decrease with the increasing values of the specific gravity. The tendency is not well marked in the village and Red Sindhi cows. The character of association is linear but Murrah buffaloes appear to be an exception. The association, small as it is, is more marked in Holstein Sindhis than in Red Sindhi and village cows, and in village than in Murrah buffaloes. As between cows and buffaloes the association is more marked in the latter. The values of the coefficients of correlations shown in Table 30 confirm these conclusions. In general it may be said that there is a slight negative correlation between the percentage butter fat and the specific gravity.

The association of percentage solids-not-fat with specific gravity is distinctly linear in character. Diagrams (3·2) and (4·2) show that the mean percentage solids-not-fat is more or less uniformly increasing with the values of the specific gravity. Unlike with the percentage butter fat, the relationship is direct but is of a much higher degree. Holstein Sindhi of all groups shows the least correlation. The coefficient of correlation in the Holstein Sindhi group is only 0·24 whereas in other groups it varies from 0·61 to 0·80. It is worth noting that the Holstein Sindhi group which shows the maximum correlation between the percentage butter fat and the specific gravity, shows the least correlation between the percentage solids-not-fat and the specific gravity. It may be noted in passing that the close relationship of solids-not-fat with the specific gravity forms the basis underlying the prediction of the proportion of solids-not-fat from a knowledge of the specific gravity.

The percentage lactose is another character with which specific gravity shows a high positive correlation. Diagrams (3·3) and (4·3) contain a suggestion that the relationship is slightly parabolic in character with the concavity facing the horizontal axis. Once again the Holstein Sindhi group shows the least correlation. The coefficient of correlation is of the order of 0·60 in all groups excepting the Holstein Sindhi group where it has a value of 0·42.

Diagrams (3·4) and (4·4) do not show much of an association between the percentage crude protein and the specific gravity. The Holstein Sindhi group shows no association whatever. Graphs for other groups suggest a non-linear relationship. In the village group the average crude protein shows a tendency to decrease with the increasing values of the specific gravity up to 1·02855, but above that value the percentage of crude protein increases. Much the same but a little more complex behaviour is noticeable in other groups. The coefficients of correlation which have slight positive values in all but the Hostein Sindhi group appear to be of doubtful value as a measure of the intensity of relationship.

Diagram (3·5) for cows' milk does not reveal any association between the percentage ash and the specific gravity but the one for buffaloes *viz.*, (4·5) shows a slight positive correlation. This is confirmed by the values of the coefficients of correlation which are small and non-significant in all groups of cows and have the values of 0·25 in Murrah buffaloes and 0·38 in village buffaloes. The presence of a slight positive relationship of percentage ash with specific gravity in buffaloes' milk with no corresponding relationship in cows' milk is worth noting.

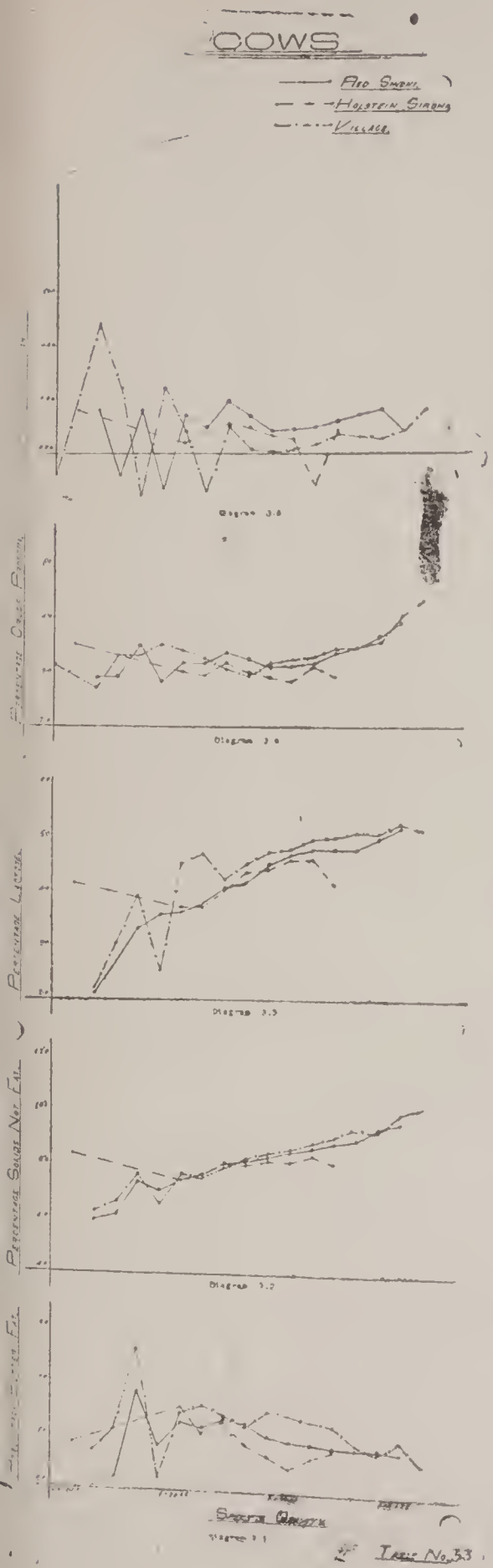


Table No. 33

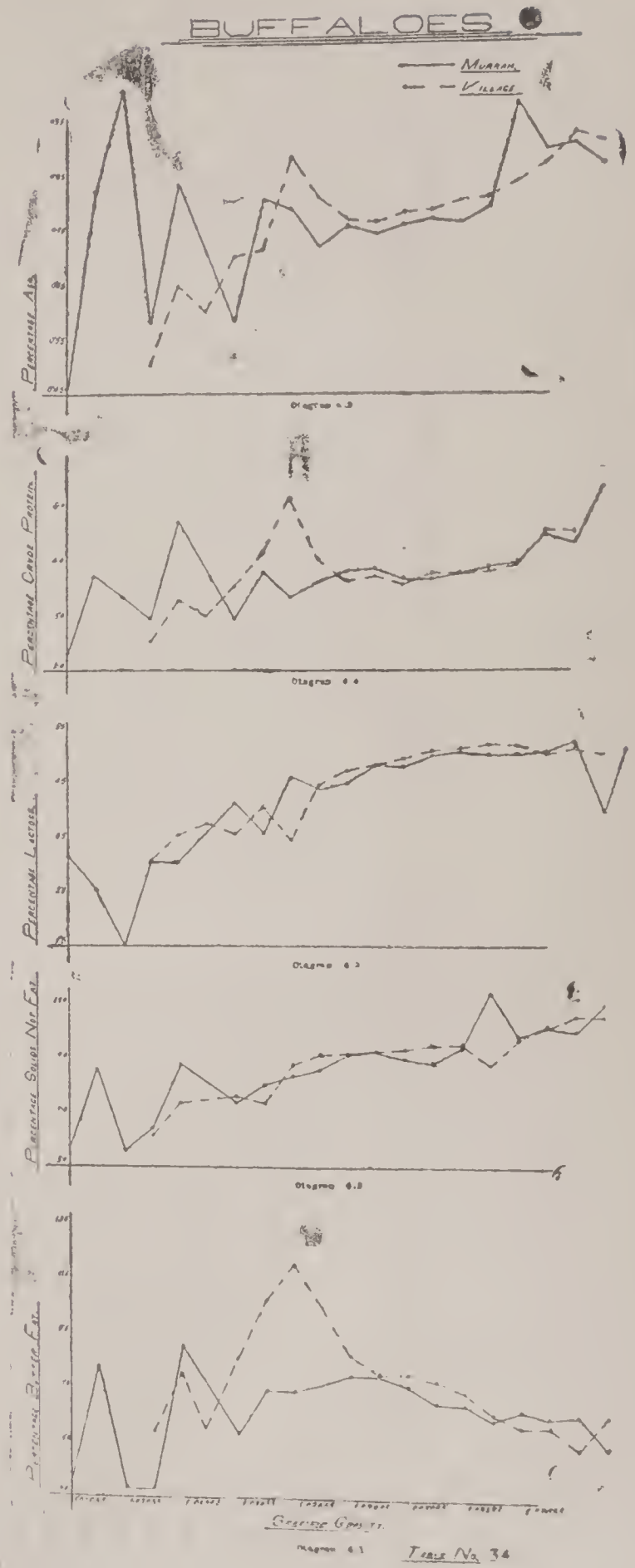


Table No. 34

TABLE 35

Mean values of specific gravity, percentage solids-not-fat, lactose, ash, crude protein and casein for values of percentage butter-fat increasing at equal intervals

Cows

Percentage butter fat	Red Sindhi							Holstein Sindhi							Village						
	No. of samples	Specific gravity	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	Percentage casein	No. of samples	Specific gravity	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	Percentage casein	No. of samples	Specific gravity	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	Percentage casein
2·205	1	1·03355	8·505	4·705	0·7805	3·105															
2·605	4	1·03055	8·155	4·505	0·7205	3·155		1	1·03155	7·905	4·705	0·6605	2·505								
3·005	6	1·02955	7·305	3·838	0·6738	2·738		4	1·02955	8·305	4·655	0·7105	2·555		3	1·02955	8·038	4·505	0·7138	2·972	
3·405	19	1·02992	8·010	4·494	0·6963	2·758	2·225(5)	20	1·03005	8·085	4·445	0·7125	2·715	1·905(2)	7	1·03069	8·105	4·448	0·7062	3·076	2·205(2)
3·805	63	1·03079	8·299	4·708	0·7132	2·911	2·030(8)	35	1·03009	8·042	4·585	0·7011	2·774	1·955(4)	7	1·03155	8·534	4·219	0·7633	3·105	2·605(2)
4·205	85	1·03149	8·559	4·799	0·7259	2·999	2·231(19)	45	1·02975	8·132	4·452	0·7361	2·901	1·996(11)	15	1·03128	8·865	4·825	0·7165	3·219	2·372(3)
4·605	111	1·03147	8·591	4·730	0·7380	3·128	2·435(23)	18	1·02844	8·061	4·438	0·7272	2·927	2·148(14)	22	1·03164	8·778	3·996	0·7241	3·296	2·483(9)
5·005	95	1·03105	8·507	4·581	0·7632	3·233	2·410(19)	19	1·02960	8·158	4·347	0·7468	3·126	2·185(10)	21	1·03165	8·810	4·772	0·7405	3·362	2·625(5)
5·405	70	1·03083	8·548	4·492	0·7653	3·368	2·388(17)	13	1·02863	7·920	4·028	0·7497	3·074	2·455(4)	19	1·03102	8·694	4·905	0·7027	3·327	2·605(2)
5·805	53	1·03021	8·463	4·388	0·7669	3·414	2·638(9)	6	1·02888	8·005	4·138	0·7738	3·405	2·145(5)	21	1·03022	8·610	4·734	0·7233	3·324	2·425(5)
6·205	28	1·03069	8·648	4·498	0·7848	3·526	2·705(4)	2	1·02755	8·005	3·905	0·7705	3·505		17	1·03179	8·940	5·293	0·7099	3·399	2·738(6)
6·605	16	1·03043	8·830	4·355	0·8280	3·743	3·105(4)	3	1·02688	7·905	3·705	0·7805	3·305		20	1·03045	8·505	4·185	0·7105	3·294	2·838(3)
7·005	12	1·02955	8·705	4·205	0·8172	3·722	2·705(5)	4	1·02930	8·055	4·055	0·7705	3·455	2·305(1)	15	1·03055	8·945	3·612	0·7245	3·572	3·105(2)
7·405	6	1·02844	8·283	4·016	0·8338	3·705	3·105(1)	1	1·02855	8·305	3·305	0·8605	3·855	2·305(1)	12	1·03013	8·672	4·938	0·7305	3·422	2·905(1)
7·805	1	1·03055	8·905	4·305	0·7805	3·905									3	1·03055	8·905	4·572	0·7538	3·705	
8·205	2	1·02655	8·405	3·805	0·8605	3·905									2	1·02705	8·105	4·205	0·7005	3·205	
8·605	..	.	..	.	..	..									1	1·02855	8·105	4·505	0·7405	2·905	
9·005	2	1·02805	9·005	4·405	0·7605	3·605									..	..	.	..	.	..	
9·405															1	1·03255	9·505	4·505	0·8605	4·105	
Total	533						(114)	171						(52)	186						(40)
Coefficient of correlation		—0·19*	0·19*	—0·26*	0·41*	0·57*	0·56*		—0·35*	—0·06	—0·44*	0·40*	0·54*	0·42*		—0·17*	0·07*	0·09	—0·05	0·21*	0·47*

N.B.—Figures in brackets indicate the number of samples for the percentage of casein.

TABLE 36

Mean values of specific gravity, percentage solids-not-fat, lactose, ash, crude protein and casein for values of percentage butter fat increasing at equal intervals.

BUFFALOES

Percentage butter fat	Murrah							Village						
	No. of samples	Specific gravity	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein	Percentage casein	No. of samples	Specific gravity	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude-protein	Percentage casein
3·405	1	1·02555	5·505	2·705	0·9005	3·305	2·305(1)							
3·805	2	1·02105	5·905	2·305	0·8205	3·105	..							
4·205	3	1·02455	6·972	3·438	0·6072	2·972	..	4	1·02955	9·605	5·105	0·8205	3·505	2·705(2)
4·605	2	1·03355	9·605	5·205	0·7005	3·605	2·905(1)	5	1·03195	9·225	4·885	0·7725	3·505	2·505(1)
5·005	3	1·03255	9·372	4·905	0·7405	3·858	..	18	1·03311	9·349	4·994	0·7961	3·594	2·838(3)
5·405	13	1·03224	9·444	4·782	0·7651	3·674	2·905(2)	20	1·03375	9·615	5·065	0·8225	3·835	2·805(2)
5·805	26	1·03213	9·105	4·905	0·7790	3·513	2·705(2)	31	1·03182	9·453	5·008	0·7508	3·686	3·225(5)
6·205	41	1·03214	9·325	5·081	0·7522	3·564	2·630(8)	35	1·03318	9·579	5·019	0·7965	3·802	3·048(7)
6·605	48	1·03220	9·426	4·951	0·7672	3·718	2·876(14)	31	1·03239	9·402	4·976	0·7831	3·712	2·865(5)
7·005	37	1·03215	9·370	4·954	0·7729	3·727	3·105(13)	52	1·03203	9·313	5·017	0·7843	3·655	2·755(12)
7·405	33	1·03167	9·196	4·881	0·7526	3·766	2·972(9)	68	1·03114	9·396	5·023	0·7811	3·687	2·972(15)
7·805	35	1·03069	9·162	4·808	0·7611	3·785	3·005(6)	43	1·03150	9·403	4·979	0·7842	3·714	3·048(7)
8·205	16	1·02986	9·180	4·612	0·7355	3·805	3·105(3)	57	1·03087	9·235	4·986	0·7728	3·744	3·048(14)
8·605	11	1·03073	9·287	4·705	0·7841	4·160	3·405(4)	41	1·03070	9·310	4·925	0·7825	3·817	3·141(11)
9·005	15	1·03068	8·985	4·465	0·7778	4·092	3·305(3)	30	1·03038	9·298	4·932	0·7752	3·812	3·080(8)
9·405	7	1·02926	9·218	4·648	0.7862	4·248	3·305(2)	9	1·02999	9·416	4·749	0·7938	3·972	3·105(5)
9·805	4	1·02755	8·955	4·455	0·7405	3·905	..	8	1·02943	9·805	4·580	0·7855	4·255	3·305(1)
10·205	3	1·02955	9·638	4·572	0·8338	4·372	..	17	1·02984	9·529	4·552	0·8346	4·293	3·305(2)
10·605	3	1·02955	9·572	4·238	0·8072	4·638	..	7	1·02941	9·562	4·391	0·8262	4·391	..
11·005	1	1·02555	8·705	3·505	0·9005	4·505	3·505(1)	5	1·02875	9·425	4·345	0·7965	4·265	..
11·405	..	..	..	..	.	..	..	1	1·02755	8·505	4·305	0·8605	4·105	..
11·805	1	1·02255	8·105	3·505	0·7805	4·105	..	7	1·02883	9·334	3·991	0·7976	4·705	..
12·205	2	1·02255	8·905	2·805	0·8605	5·005	..	5	1·02715	8·945	4·305	0·8525	4·425	3·505(1)
12·605	1	1·02855	9·505	4·105	0·8605	5·305	..	1	1·02555	8·505	4·105	0·9005	4·505	
13·005														
13·405														
13·805								1	1·02255	8·905	3·505	0·9405	4·705	
Total .	308						(69)	496						(101)
Coefficient of correlation.		−·0·27*	0·09	−·0·18*	0·13*	0·46*	0·57*		0·53*	0·06	−·0·28*	0·16	0·24*	0·34*

N B Figures in brackets indicate the number of samples for the percentage of casein

Butter fat and other factors.

Tables 35 and 36 and Diagrams 5 and 6 show the average values of the various factors for ascending values of the percentage of butter fat. The feature referred to earlier of irregular variations at end values is seen to be present in these diagrams.

We have already seen that the percentage of butter fat has a slight negative correlation with the specific gravity. As regards the association with the solids-not-at the Diagrams (5·2) and (6·2) show that except in the Red Sindhi cows where there seems to be a tendency for the percentage of solids-not-fat to generally increase with the values of the percentage butter fat, there is no association. Even in the Red Sindhi group the diagram points out only a slight positive relationship and no more. Table 30 shows a significant value of 0·19 for the coefficient of correlation between the percentage of butter fat and the solids-not-fat in the Red Sindhi group. The values of the coefficient of correlation for other groups are small and statistically not significant.

Figures (5·3) and (6·3) show that the percentage of butter fat has an inverse association with the percentage of lactose in all excepting the village group of cows. The relationship is linear but more marked in the Holstein Sindhi cows and in the village buffaloes. The table of the coefficients of correlation shows a significant value of - 0·44 for the Holstein Sindhi cows and —0·38 for the village buffaloes. The value for the village group of cows is insignificant.

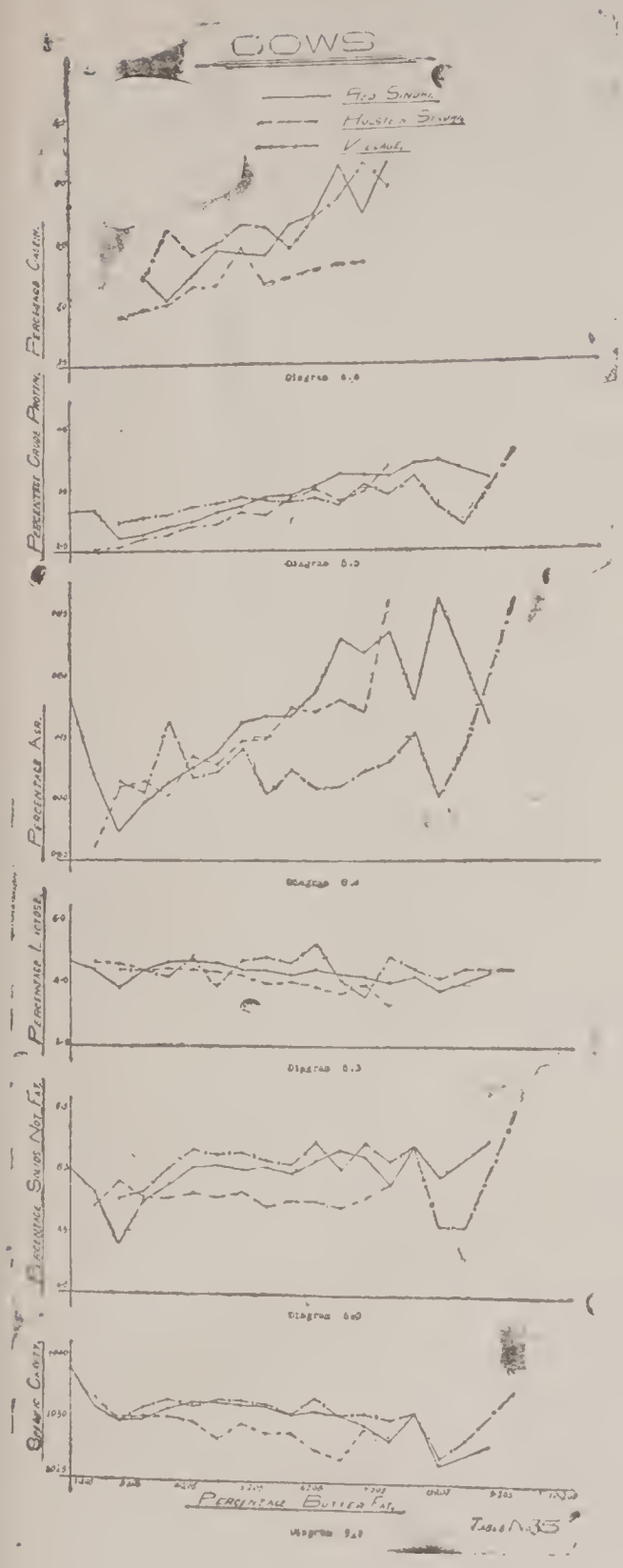
Diagrams (5·4) and (6·4) for the regression of the ash content on the percentage of butter fat show that there is a linear correlation between the percentage of butter fat and the percentage of ash in Red Sindhis and Holstein Sindhi cows, but there is little or no correlation in the case of buffaloes. The village group of cows also shows no correlation. The coefficients of correlation in the Red Sindhi and Holstein Sindhi groups are 0·41 and 0·40 respectively. For the village group the coefficient of correlation is insignificant. The coefficients for the two buffalo groups have small positive values namely 0·13 and 0·06 but the former is significant at the 5 per cent level. It is worth noting that the behaviour of ash with the percentage of butter fat in cows and in buffaloes is different from that observed between ash and specific gravity in the two species.

The percentage of butter fat shows a distinctly linear association with the percentage of crude protein. The association is positive, and closer than with other factors. The village group once again shows a poor correlation. Coefficients are 0·57 and 0·54 in Red Sindhi and Holstein Sindhi cows and 0·46 and 0·34 in Murrah and village buffaloes.

In addition to the above correlation the correlation between percentage butter fat and casein, which is considered to be of some interest by analysts, has also been worked out. It will be seen from Diagrams (5·6) and (6·6) that there is a positive linear relationship between the percentages of butter fat and casein. The coefficient of correlation is of the order of 0·5 except in village buffaloes where it is rather low.

Solids-not-fat and other factors.

Tables 37 and 38 and the corresponding Diagrams 7 and 8 give the mean values of the various factors for ascending values of the percentage solids-not-fat. The irregular variation at the end values is present in the diagrams and it is therefore necessary to limit the attention to the middle portion for reading the association between the percentage solids not-fat and other factors.


COWS
Red Sindhi
Hussein Sindhi
V Grade
Percentage Casein
Diagram 6.6
Percentage Curd Protein
Diagram 6.5
Percentage Ash
Diagram 6.4
Percentage Lactose
Diagram 6.3
Percentage Solids Not Fat
Diagram 6.2
Specific Gravity
Percentage Butter Fat
Diagram 6.1
Table No 35

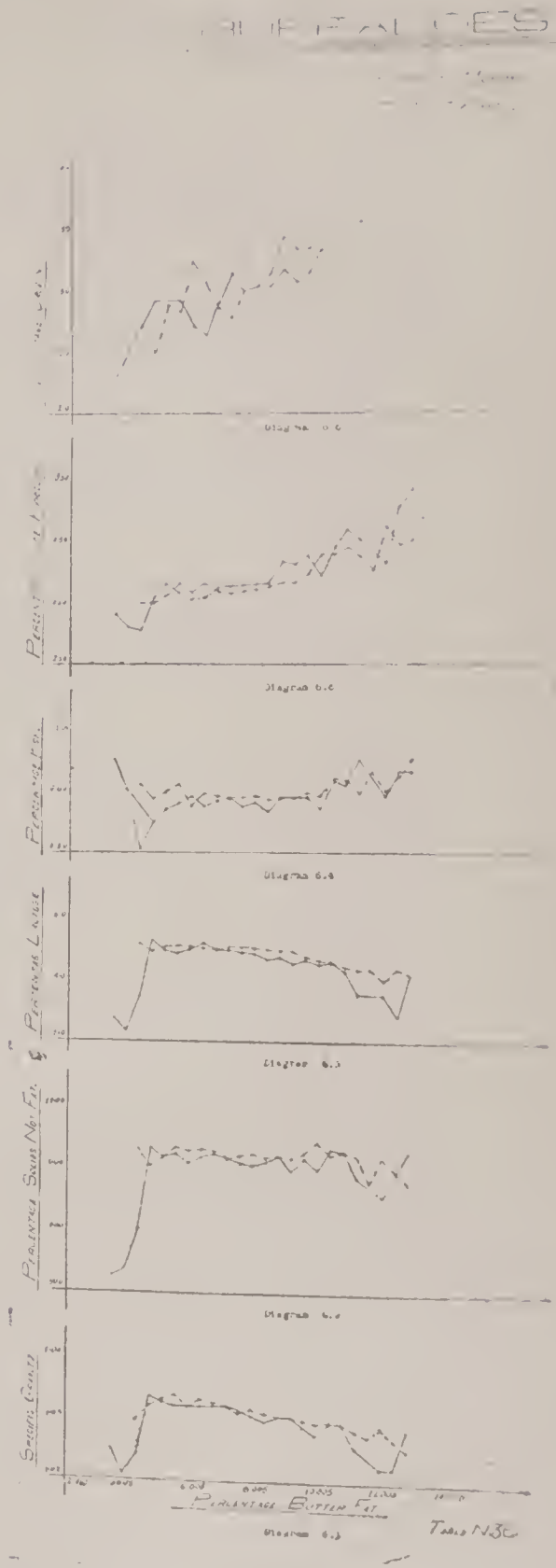


Diagram 6.6
Diagram 6.5
Diagram 6.4
Diagram 6.3
Diagram 6.2
Specific Gravity
Percentage Butter Fat
Diagram 6.1
Table No 36

TABLE 37

Mean values of specific gravity, percentage butter fat, lactose, ash and crude protein for values of percentage solids-not-fat increasing at equal intervals

Cows

Percentage solids-not-fat	Sindhi						Holstein Sindhi						Village					
	No. of samples	Specific gravity	Percentage butter-fat	Percentage lactose	Percentage ash	Percentage crude-protein	No. of samples	Specific gravity	Percentage butter fat	Percentage lactose	Percentage ash	Percentage crude protein	No. of samples	Specific gravity	Percentage butter fat	Percentage lactose	Percentage ash	Percentage crude protein
5·705	1	1·03055	3·005	2·905	0·5005	2·105												
5·905	1	1·02155	3·005	2·105	0·7805	2·905							1	1·02155	3·205	2·105	0·9405	2·105
6·105	1	1·02255	3·405	2·705	0·6605	2·905							..	..	..	..	.	..
6·305	..	..	.	..	..	..							..	.	..	.	.	.
6·505	2	1·02805	4·205	4·405	0·6405	2·705							3	1·02285	3·472	3·305	0·8605	3·372
6·705	1	1·02455	3·405	3·305	0·6205	2·505	1	1·03155	5·805	4·305	0·8205	3·705	1	1·02255	4·205	3·705	0·8205	3·305
6·905	1	1·02555	3·405	3·905	0·6205	2·505	1	1·02955	4·605	4·705	0·6605	2·705	1	1·02955	3·805	4·705	0·7405	2·905
7·105	2	1·02605	3·205	3·605	0·7005	2·705	1	1·02955	4·205	4·705	0·8205	2·705	..		..	.		
7·305	9	1·02666	5·183	3·661	0·7761	3·105	3	1·02688	4·605	3·972	0·7005	2·705	1	1·03055	4·605	3·705	0·7405	3·105
7·505	10	1·02805	5·045	3·965	0·7405	3·125	7	1·02784	5·176	4·048	0·7348	2·762	3	1·02688	3·938	4·238	0·7405	3·238
7·705	14	1·02769	5·548	4·048	0·7405	3·105	22	1·02928	4·169	4·341	0·7205	2·823	7	1·02784	4·091	4·305	0·6662	2·991
7·905	36	1·02919	4·983	4·211	0·7494	3·077	40	1·02935	4·365	4·330	0·7305	2·820	8	1·02880	4·180	4·655	0·7255	3·130
8·105	52	1·03013	4·874	4·509	0·7274	3·055	44	1·02973	4·296	4·550	0·7341	3·060	9	1·02944	3·827	4·416	0·7494	2·949
8·305	104	1·03063	4·670	4·538	0·7443	3·017	28	1·02955	4·719	4·312	0·7405	3·184	16	1·02961	4·055	4·668	0·7080	2·980
8·505	106	1·03113	4·677	4·709	0·7386	3·073	10	1·03065	3·965	4·445	0·7645	3·105	28	1·03030	4·369	4·741	0·7287	3·194
8·705	95	1·03169	4·849	4·753	0·7510	3·267	8	1·03005	4·655	4·405	0·7555	3·130	25	1·03115	4·045	5·001	0·6973	3·177
8·905	73	1·03184	5·235	4·702	0·7772	3·426	1	1·02955	5·805	4·905	0·7405	3·305	23	1·03194	4·118	5·001	0·7057	3·375
9·105	47	1·03198	5·473	4·731	0·7882	3·577	1	1·02955	5·405	4·305	0·7405	3·105	13	1·03224	4·174	4·828	0·7067	3·472
9·305	14	1·03205	5·462	4·891	0·7891	3·634	1	1·03155	5·005	4·905	0·6605	3·505	22	1·03323	3·960	5·123	0·7169	3·480
9·505	12	1·03380	5·272	4·722	0·8005	3·922	..	..	..	..	..	..	11	1·03291	4·387	4·996	0·7627	3·723
9·705	..	.	..	.	..	..	1	1·02955	3·005	4·705	0·7005	2·505	7	1·03369	4·091	5·105	0·7691	3·819
9·905	2	1·03155	4·805	4·605	0·7405	3·105	2	1·02955	3·805	4·505	0·7405	2·705	3	1·03522	3·605	4·972	0·7538	4·288
10·105					..	..							3	1·03488	4·338	5·105	0·7005	4·305
10·305	..	..	..	.	..	..							..	.	..	..	.	..
10·505	2	1·03105	5·605	4·505	0·7605	3·505							1	1·03555	3·605	5·105	0·7005	4·505
10·705	1	1·03455	5·405	5·105	0·8205	4·705												
Total	586						171						186					
Coefficient of correlation.		0·67*	0·19*	0·46*	0·25*	0·47*		0·24*	0·06	0·15	0·10	0·19*		0·80*	0·07	0·67*	0·11	0·60*

TABLE 38

Mean values of specific gravity, percentage butter fat, lactose, ash and crude protein for values of percentage solids-not-fat, increasing at equal intervals

BUFFALOES

Percentage solids-not-fat	Murrah						Vilia					
	No. of samples	Specific gravity	Percentage butter fat	Percentage lactose	Percentage ash	Percentage crude-protein	No. of samples	Specific gravity	Percentage butter fat	Percentage lactose	Percentage ash	Percentage crude-protein
5·305	1	1·01855	3·805	1·505	1·0605	3·305						
5·705	2	1·02455	6·605	4·105	0·6205	2·805						
5·905	..	..	..	..	..	..						
6·105	..	..	..	..	..	..	1	1·02155	5·805	3·105	0·5005	2·505
6·305	1	1·02155	3·805	3·105	0·5805	2·905	..	..	..	..	..	..
6·505	..	..	..	..	..	..	2	1·02255	5·205	3·505	0·5005	2·505
6·705	1	1·02755	5·405	3·105	0·5405	2·705	.	.	.	.	.	.
6·905	1	1·02555	3·405	2·705	0·9005	3·305	..	..	..	..	..	..
7·105	..	..	..	..	..	..	2	1·02705	6·805	4·305	0·6805	3·205
7·305	1	1·02455	5·805	4·105	0·5805	2·905	2	1·02405	7·805	3·705	0·6605	3·205
7·505	2	1·02955	5·405	4·605	0·6605	3·305	..	..	..	..	..	..
7·705	1	1·02855	4·205	3·105	0·7805	3·705	1	1·03055	7·805	5·305	0·7005	3·305
7·905	3	1·02588	6·472	4·105	0·7405	3·372	4	1·03030	6·805	4·505	0·7405	3·355
8·105	2	1·02655	9·605	4·105	0·7405	3·805	4	1·02855	6·805	4·505	0·7405	3·105
8·305	5	1·02815	8·765	4·145	0·7965	4·025	5	1·02895	5·925	4·385	0·7325	3·265
8·505	11	1·02873	7·332	4·541	0·7187	3·432	13	1·02932	7·989	4·536	0·7528	3·597
8·705	17	1·02914	7·335	4·658	0·7475	3·470	22	1·02987	8·060	4·805	0·7605	3·441
8·905	39	1·03063	7·179	4·864	0·7374	3·520	39	1·02865	8·205	4·797	0·7518	3·572
9·105	52	1·03109	7·467	4·855	0·7490	3·647	73	1·03073	7·967	4·930	0·7602	3·606
9·305	55	1·03211	6·932	5·021	0·7572	3·690	88	1·03168	7·687	5·028	0·7832	3·898
9·505	45	1·03188	6·943	4·945	0·7672	3·932	89	1·03212	7·607	5·051	0·7967	3·793
9·705	30	1·03242	7·405	4·912	0·7845	3·852	59	1·03202	7·717	4·966	0·8008	3·966
9·905	19	1·03287	6·752	4·989	0·8205	4·116	32	1·03321	6·918	5·005	0·8268	4·061
10·105	5	1·03435	7·325	4·305	0·9485	4·985	21	1·03236	8·015	4·886	0·8243	4·267
10·305	7	1·03226	6·891	4·791	0·8091	4·162	14	1·03419	7·291	5·005	0·8434	4·191
10·505	3	1·03555	7·005	4·572	0·9538	4·705	9	1·03511	6·472	4·861	0·9405	4·704
10·705	.	..	..	..	..	..	10	1·03485	6·845	4·965	0·9005	4·725
10·905	4	1·03255	6·205	4·405	0·8405	5·205	3	1·03622	5·272	5·105	0·9138	4·438
11·105	1	1·02955	5·405	4·705	0·7405	3·905	.	..	..	..	..	..
11·305							1	1·03455	4·205	5·905	1·0205	3·905
11·505							1	1·02955	6·205	4·105	1·0205	5·505
11·705							.	.	.	..	..	.
11·905							..	.	.	..	.	.
12·105							..	..	..	..	..	.
12·305							1	1·03055	9·805	4·903	0·7405	4·105
Total	308						496					
Coefficient of correlation		0·64*	0·09	0·43*	0·86*	0·55*		0·61*	—0·06	0·31*	0·52*	0·57*

We have already discussed the correlations of solids not-fat content with specific gravity and butter fat content. Regarding the correlation of lactose with solids-not-fat Diagrams (7·3) and (8·3) particularly the latter relating to buffaloes, suggest a parabolic association. The association seems to be high and positive. Among the cows, the Holstein Sindhi group shows the least association. The actual value of the coefficient of correlation in this group is only 0·15 which is statistically not significant. In the village and Red Sindhi groups the coefficients are 0·67 and 0·16, while in Murrah and village buffaloes the values are 0·43 and 0·31. It should be noted that lactose is a part of the solids-not fat and therefore a part of the association is of a spurious character.

Diagrams (7·4) and (8·4) show the relationship of solids-not-fat with ash. There is an evidence of a slight positive relationship in Red Sindhi cows but there does not appear to be any association in the other two groups of cows. In buffaloes the relationship is closer than in Red Sindhi cows but there is a suggestion of a non-linear type of relation between the two factors. The values of the coefficient of correlation are 0·36 for the Murrah group, 0·52 for village buffaloes and 0·25 for the Red Sindhi group of cows.

Diagrams (7·5) and (8·5) show a high association between the percentage of solids-not-fat and the percentage of crude protein. The association is direct and is a little more marked in buffaloes than in cows. Among the cows, the Holstein Sindhi group shows the least correlation. There is a suggestion of a non-linear relationship. The value of the coefficient of correlation is of the order of 0·5 for Red Sindhi cows and 0·6 for village cows and Murrah and village buffaloes.

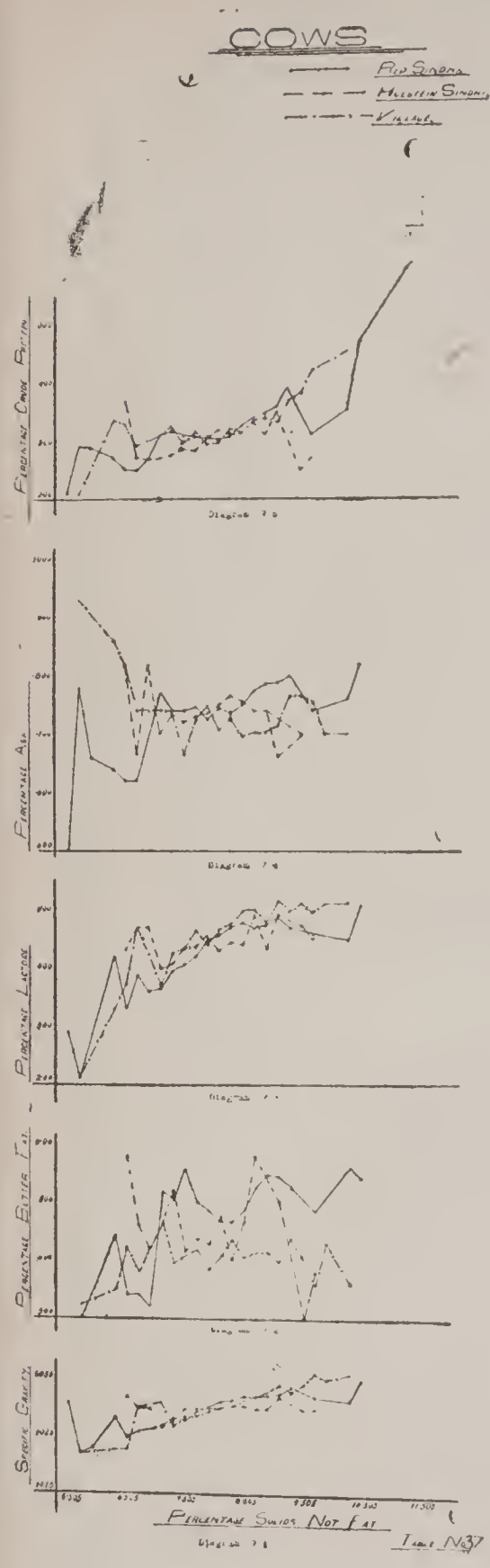
Lactose and other factors.

The regression of the percentage of lactose on other factors are shown in Tables 39 and 40 and represented graphically in Diagrams 9 and 10.

The relationships of lactose with milk yield, specific gravity, butter fat and solids-not-fat have been already discussed. Diagrams (9·4) shows a distinctly negative association between the percentages of lactose and of ash in cows' milk, but Diagram (10·4) shows little or no relationship in buffaloes' milk. The values of the coefficient of correlation are 0·31 in Red Sindhi and 0·38 in other two groups of cows.

Lactose content shows a negative association with the percentage of crude protein in both cows and buffaloes, but the village group of cows seems to be an exception. The two factors seem to be correlated to more or less the same degree in the two groups of buffaloes but among the cows the degree of relationship seems to vary materially from group to group. The coefficients of correlation are —0·56 for the Holstein Sindhi group, —0·29 for the Red Sindhi group and +0·16 for the village group but the last one is significant only at the 5 per cent level. In buffaloes the values are —0·23 for the Murrah buffaloes and —0·25 for the village buffaloes.

The relationship between percentage lactose and percentage chlorine is considered to be of some interest for detecting adulteration of milk and has been worked out in addition to the above correlations. Graphs (9·6) and (10·6) show that the variations in the chlorine and lactose content follow closely a linear law. There seems to be a high negative relationship between the two. The association is seen to be closer in cows' than in buffaloes' milk. The coefficient of correlation is of the order of 0·6 in cows and 0·5 in buffaloes.


COWS
RED SINDHI
MONTGOMERY SINDHI
KANKREJ
PERCENTAGE CRUDE PROTEIN
PERCENTAGE ASH
PERCENTAGE LACTOSE
PERCENTAGE BUTTER FAT
SPECIFIC GRAVITY
PERCENTAGE SOLIDS NOT FAT
TABLE No37

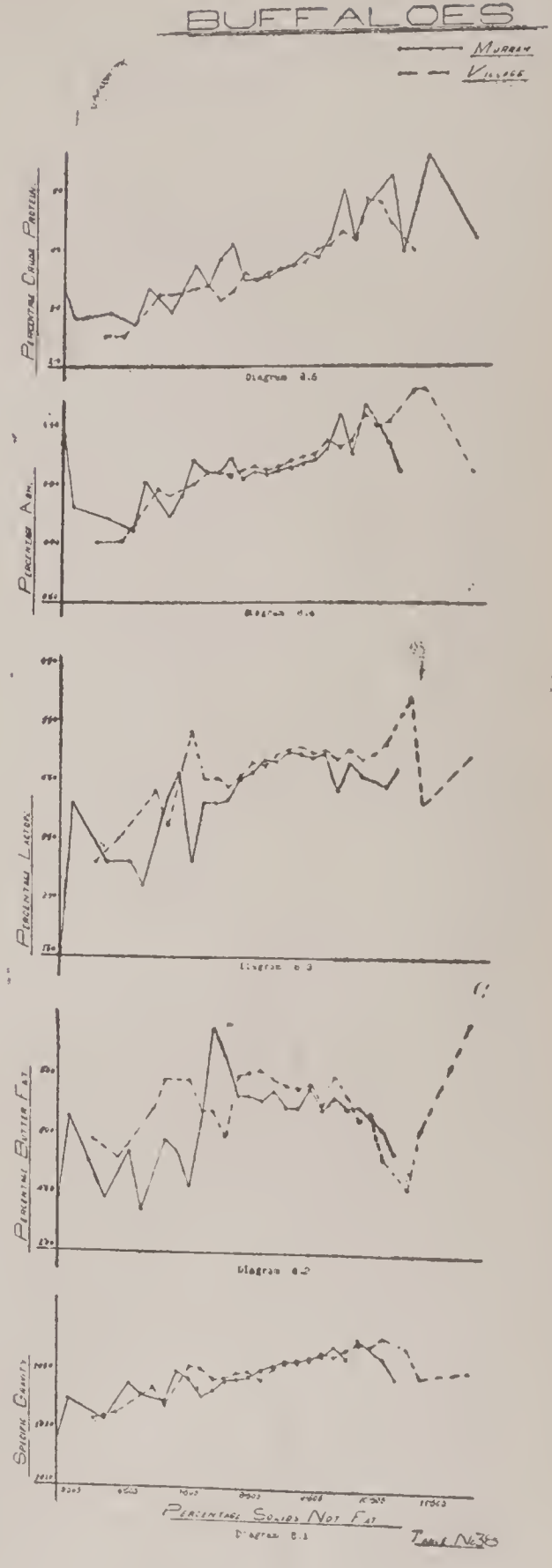

BUFFALOES
MURRAH
KANKREJ
PERCENTAGE CRUDE PROTEIN
PERCENTAGE ASH
PERCENTAGE LACTOSE
PERCENTAGE BUTTER FAT
SPECIFIC GRAVITY
PERCENTAGE SOLIDS NOT FAT
TABLE No38

TABLE 39.

Mean values of specific gravity, percentage butter fat, solids-not-fat, ash, crude protein and chlorine for values of percentage lactose increasing at equal intervals.

Percentage lactose	Cows																							
	Red Sindhi							Holstein Sindhi							Village									
	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage ash	Percentage crude-protein	Percentage chlorine	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage ash	Percentage crude-protein	Percentage chlorine	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage ash	Percentage crude-protein	Percentage chlorine			
2·105	1	1·02155	3·005	5·905	0·7805	2·905									1	1·02155	3·805	5·905	0·9405	2·105				
2·305	..	..	..	..	..	..									2	1·02205	4·805	6·505	0·8805	3·305	0·1755(2)			
2·505	..	..	..	..	..	..									1	1·02455	3·405	6·505	0·8205	3·505				
2·705	1	1·02255	3·405	6·105	0·6605	2·905																		
2·905	1	1·03055	3·005	5·705	0·5005	2·105																		
3·105	8	1·02730	5·155	7·655	0·8955	3·655	0·1126(7)	2	1·02755	4·205	7·805	0·7005	3·305	0·1155(1)	3	1·03022	5·405	8·372	0·7005	2·705	0·1022(3)			
3·305	7	1·02741	5·862	7·819	0·8833	3·619	0·1280(4)	3	1·02822	6·072	8·238	0·8472	3·838	0·1555(3)										
3·505	7	1·02741	5·862	7·848	0·8262	3·591	0·1538(6)	5	1·02935	4·445	7·945	0·7245	3·305	0·1588(3)	4	1·20705	5·205	7·455	0·7805	3·155	0·1355(3)			
3·705	15	1·02808	5·298	7·972	0·8152	3·518	0·1255(10)	7	1·02726	5·748	7·791	0·7519	3·191	0·1605(6)	4	1·02755	4·705	7·805	0·7305	3·055	0·1205(4)			
3·905	18	1·02844	5·538	7·949	0·7649	3·327	0·1273(11)	7	1·02884	5·405	7·876	0·7462	3·048	0·1275(5)	3	1·03088	6·072	8·438	0·6872	3·638	0·0355(1)			
4·105	32	1·02989	5·243	8·318	0·7517	3·311	0·1055(22)	22	1·02896	5·005	8·151	0·7787	3·296	0·1233(18)	9	1·02966	3·805	8·149	0·7272	2·883	0·0984(7)			
4·305	58	1·03060	5·322	8·443	0·7660	3·312	0·0949(32)	31	1·02942	4·347	8·053	0·7431	2·995	0·1101(26)	20	1·02990	6·125	8·455	0·7305	3·295	0·0817(13)			
4·505	96	1·03089	5·084	8·522	0·7505	3·295	0·0774(52)	39	1·02963	4·174	8·090	0·7292	2·797	0·1105(28)	31	1·03126	5·637	8·711	0·7418	3·376	0·0833(27)			
4·705	148	1·03133	4·967	8·469	0·7562	3·205	0·0754(91)	33	1·03013	3·951	8·051	0·7102	2·687	0·0930(24)	37	1·03090	6·119	8·183	0·7189	3·343	0·0695(30)			
4·905	127	1·03161	4·567	8·611	0·7301	3·069	0·0663(62)	15	1·03028	4·205	8·265	0·7058	2·758	0·0898(7)	34	1·03237	5·617	9·011	0·7205	3·381	0·0672(29)			
5·105	47	1·03191	4·375	8·735	0·7218	2·986	0·0631(21)	6	1·03055	3·872	8·272	0·7138	2·705	0·0780(4)	30	1·03258	5·365	9·112	0·6978	3·305	0·0673(22)			
5·305	15	1·03195	4·392	8·612	0·7058	2·972	0·0655(5)	1	1·02855	4·605	8·105	0·7005	2·705		6	1·03172	4·472	8·705	0·7005	3·005	0·0655(4)			
5·505	4	1·03105	4·605	9·105	0·7705	3·305	0·0255(1)								1	1·03555	4·605	9·905	0·7405	4·105				
5·705	..	..	..	..	..	..	..																	
5·905	1	1·03155	4·605	8·705	0·6205	3·105																		
Total .	586						(324)	171						(125)	186						(144)			
Coefficient of correlation.		0·60*	—0·26*	0·46*	—0·34*	0·29*	—0·61*		0·42*	—0·44*	0·15	—0·38*	0·56*	—0·66*		0·61*	0·09	0·67*	—0·38*	0·16*	—0·61*			

N.B.—Figures in brackets indicate the number of samples for percentage chlorine.

TABLE 40.

Mean values of specific gravity, percentage butter fat, solids-not-fat, ash, crude protein and chlorine for values of percentage lactose increasing at equal intervals.

Percentage lactose	Murrah Buffaloes							Village Buffaloes						
	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage ash	Percentage crude protein	Percentage chlorine	No. of samples	Specific gravity	Percentage butter fat	Percentage solids-not-fat	Percentage ash	Percentage crude protein	Percentage chlorine
1·505	1	1·02055	3·805	5·505	1·0605	3·305								
1·705	..	..	..	..	..	..								
1·905	..	..	..	..	..	..								
2·105	..	..	..	..	..	..								
2·305	..	..	..	..	..	..								
2·505	2	1·02105	10·205	9·005	0·8405	4·605	0·1655(1)	1	1·02655	11·805	8·505	0·9005	5·705	
2·705	1	1·02555	3·405	6·905	0·9005	3·305	0·1655(1)	..	..	..	..	..	..	
2·905	..	..	..	..	..	..	....	..	..	..	..	..	..	
3·105	5	1·02175	5·965	6·945	0·6445	3·225	0·0488(3)	1	1·02155	5·805	6·105	0·5005	2·505	0·0855(1)
3·305	..	..	..	..	..	..	....	1	1·02255	5·805	6·505	0·5405	2·705	....
3·505	3	1·02455	10·205	8·238	0·8472	4·105	0·1322(3)	4	1·02455	8·805	8·255	0·8005	3·805	0·0855(2)
3·705	1	1·02855	7·005	8·705	0·7005	3·905	....	2	1·02305	5·405	6·805	0·5005	2·605	0·0355(1)
3·905	7	1·03084	7·405	9·362	0·7805	4·648	0·0705(4)	7	1·02741	10·091	8·476	0·7718	3·905	0·0935(5)
4·105	8	1·02780	7·105	8·655	0·7205	3·980	0·0955(3)	13	1·02955	8·005	9·320	0·8205	4·151	0·0735(5)
4·305	19	1·03076	8·205	9·442	0·8015	4·179	0·0822(12)	29	1·03024	8·646	9·381	0·8205	4·084	0·0805(12)
4·505	23	1·03094	7·544	9·409	0·8031	4·148	0·0734(14)	38	1·03068	8·879	9·505	0·8258	4·152	0·0755(21)
4·705	44	1·03101	7·596	9·287	0·7714	3·832	0·0629(27)	49	1·03086	7·976	9·276	0·7960	3·819	0·0745(30)
4·905	67	1·03131	7·071	9·221	0·7620	3·672	0·0673(44)	95	1·03196	7·687	9·478	0·8070	3·890	0·0667(68)
5·105	80	1·03221	6·940	9·203	0·7595	3·665	0·0616(62)	141	1·03192	7·388	9·377	0·7751	3·708	0·0614(107)
5·305	38	1·03266	6·521	9·331	0·7352	3·489	0·0596(27)	78	1·03264	6·882	9·599	0·7672	3·644	0·0553(59)
5·505	6	1·03272	6·138	9·472	0·7072	3·605	0·0530(4)	32	1·03303	6·430	9·605	0·7743	3·524	0·0540(20)
5·705	1	1·03155	7·805	9·705	0·7005	3·505		2	1·03105	9·405	9·805	0·8805	3·505	0·0750(1)
5·905	1	1·03255	5·805	9·305	0·7405	3·705		3	1·03422	5·938	9·838	0·9005	3·638	0·0550(1)
6·105	..	..	..	..	..	..								
6·305	1	1·03555	6·205	9·905	0·8205	4·305								
Total .	308						(205)	496						(333)
Coefficient of correlation		0·64*	—0·18*	0·43*	—0·16*	0·23*	—0·46*		0·54*	—0·38*	0·31*	—0·06	—0·25*	053*

N.B.—Figures in brackets indicate the number of samples for percentage chlorine.

Ash and other factors.

Tables 41 and 42 and Diagrams 11 and 12 show the regressions of various factors on the ash content. It will be seen that ash shows a high linear positive association with crude protein. The association is, however, much less marked in the village cows than in the other two groups. In the two groups of buffaloes the association is of about the same degree. The values of the coefficients are of the order of 0·6 for the Red Sindhi group and the two groups of buffaloes and 0·5 for the Holstein Sindhi group. In the village group of cows the value is 0·18 which is statistically significant at the 5 percent level.

Crude protein and other factors.

The relationship between crude protein and other factors has already been discussed in the foregoing. The corresponding regression relationships have been shown in Tables 43 and 44 and Diagrams 13 and 14. The relationship of crude protein with casein is considered of some interest by analysts and has also been worked out. It will be seen from Diagrams (13·6) and (14·6) that the relationship is linear in type and very close in both cows' and buffaloes' milk. Part of the relationship is, however, spurious. The regression coefficients of percentage casein on percentage crude protein worked out as follows : 0·80 for Red Sindhi, 0·64 for Holstein Sindhi, 0·76 for village Cows and 0·71 and 0·67 for Murrah and village buffaloes respectively. The interpretation is that an increase of 1 percent in crude protein is associated on an average with an increase equal to the respective regression coefficients.

Total solids (or moisture) and other factors.

The correlation between the percentage of total solids in milk of percentage, moisture and any desired factor is easily worked out from the correlations of butter fat and solids-not-fat content with the particular factor. For, if r_{tx}, r_{fx} and r_{sx} represent the coefficients of correlation of total solids content, butter fat content and solids-not-fat content with any factor say 'X' respectively then it can be shown that the correlation between the percentage of total solids and the particular factor is given by $r_{tx} = \frac{r_{fx} S_f + r_{sx} S_s}{S_t}$ where S_f, S_s and S_t are the standard deviations of the percentage of butter fat, solids-not-fat and total solids respectively. The coefficients of correlation are shown in Table 30. Tables 45 and 46 and Diagrams 15 and 16 give the average values of the various factors for ascending values of the percentage of total solids.

COWS

Red Sindhi
Holstein Sindhi
Village

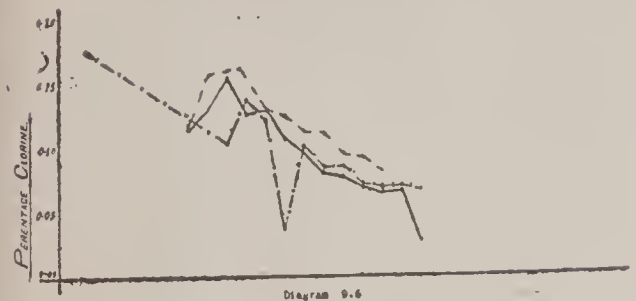


Diagram 9.6

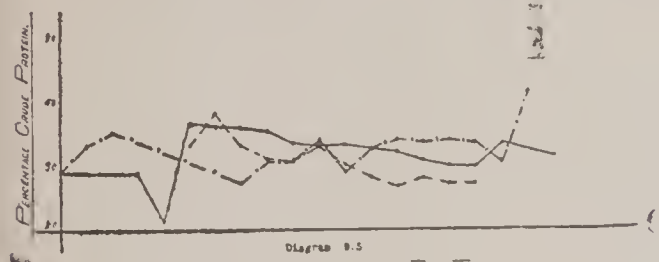


Diagram 9.5

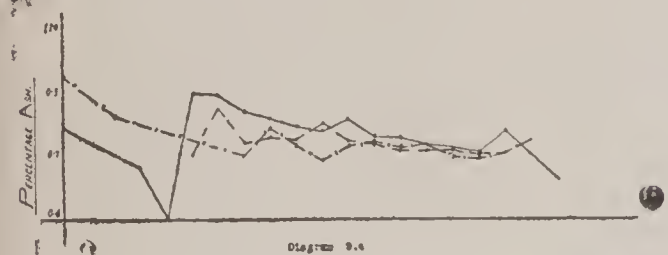


Diagram 9.4

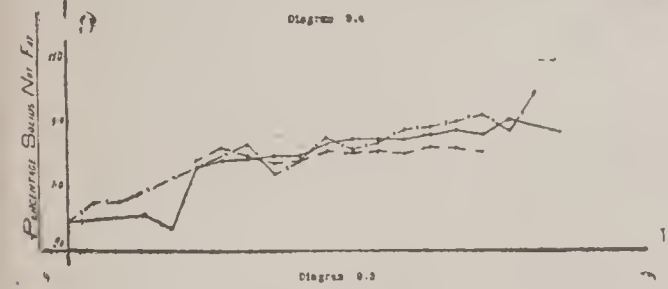


Diagram 9.3

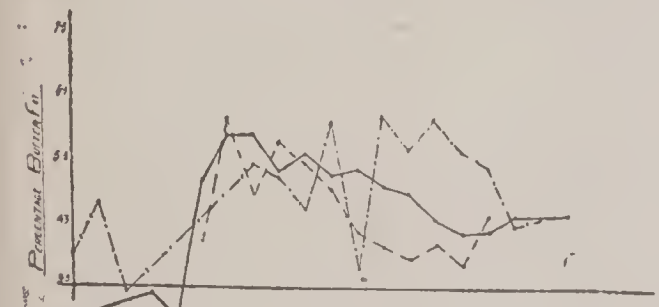
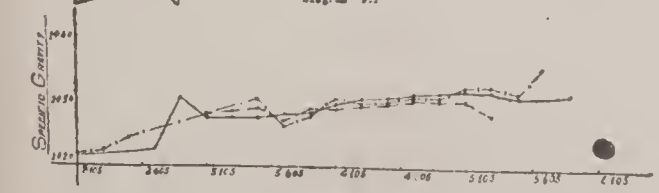


Diagram 9.2



Percentage Lactose
Diagram 9.1

Table No 38

BUFFALOES

Murrah
Village

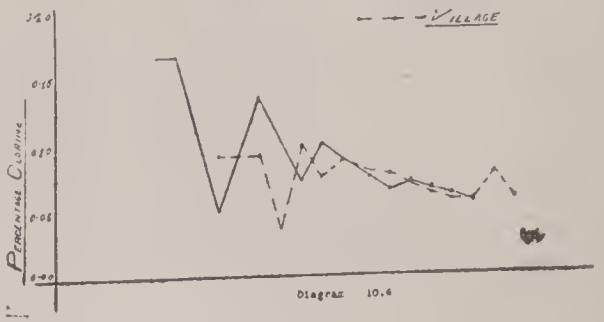


Diagram 10.6

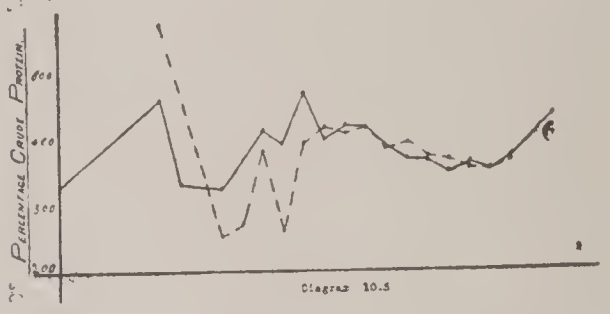


Diagram 10.5

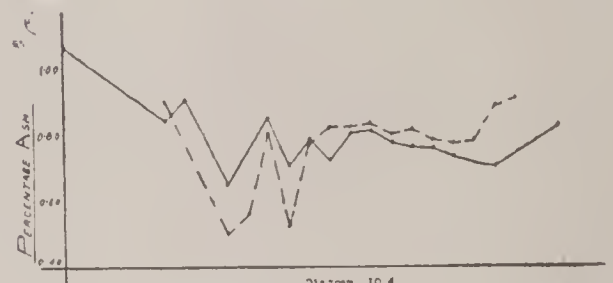


Diagram 10.4

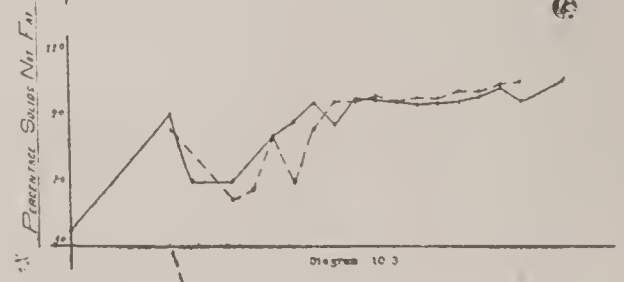


Diagram 10.3

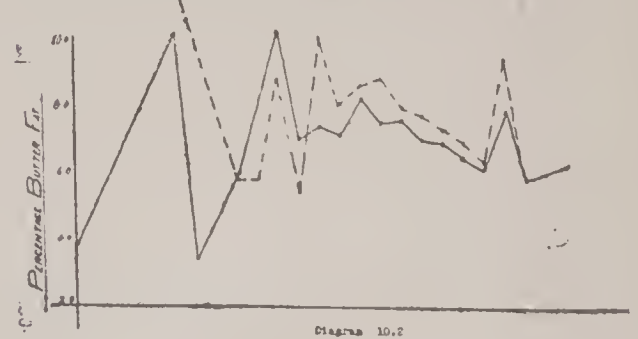
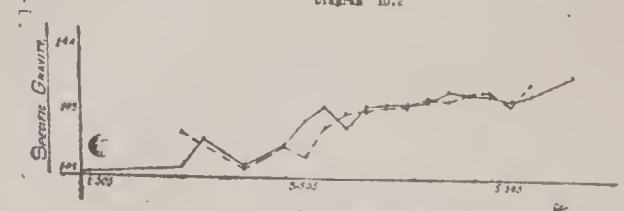


Diagram 10.2



Percentage Lactose
Diagram 10.1

Table No 40

TABLE 41.

Mean values of specific gravity, percentage butter fat, solids-not-fat, lactose, and crude protein for values of percentage ash increasing at equal intervals.

Cows.

Percentage ash.	Red Sindhi.						Holstein Sindhi.						Village.					
	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage crude protein.	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage crude protein.	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage crude protein
0·5005	1	1·03055	3·005	5·705	2·905	2·105												
0·5405	2	1·02705	3·805	7·305	3·155	2·505												
0·5805	1	1·03455	3·005	8·705	5·105	2·705							3	1·02788	5·538	8·038	4·705	2·972
0·6205	16	1·02930	4·330	8·105	4·568	2·818	2	1·02905	4·405	8·205	4·505	3·005	4	1·02955	6·005	8·605	4·805	3·105
0·6605	44	1·03048	4·232	8·300	4·787	2·796	14	1·02934	4·234	7·919	4·391	2·976	31	1·03071	5·727	8·582	4·950	3.185
0·7005	111	1·03078	4·587	8·361	4·707	2·986	54	1·02972	4·020	8·053	4·575	2·712	52	1·03142	5·490	8·924	4·924	3·282
0·7405	165	1·03105	4·872	8·489	4·686	3·109	53	1·02970	4·341	8·086	4·467	2·840	54	1·03149	5·435	8·749	4·842	3·297
0·7805	146	1·03093	5·115	8·547	4·502	3·360	37	1·02906	4·854	8·224	4·132	3·181	30	1·03172	5·352	8·638	4·678	3·602
0·8205	61	1·03180	5·464	8·898	4·515	3·603	7	1·02926	5·862	7·619	4·162	3·534	5	1·02615	5·005	7·345	3·425	3·345
0·8605	23	1·03103	5·475	8·809	4·331	3·653	3	1·02922	5·138	8·438	3·572	3·838	2	1·03105	8·405	9·005	4·705	3·605
0·9005	8	1·02955	5·805	8·480	3·805	3·830	1	1·02855	4·605	7·905	4·105	3·105	1	1·03455	5·005	9·705	4·705	4·105
0·9405	1	1·02555	7·405	7·305	3·105	3·505							2	1·02155	4·405	6·205	2·205	2·705
0·9805	5	1·02775	6·525	8·225	3·585	3·825							1	1·03255	5·405	8·505	5·105	2·705
1·0205																		
1·0605																		
1·1005																		
1·1405																		
1·1805																		
1·2205																		
1·2605	2	1·02755	5·805	8·105	3·205	4·105												
Total .	586						171						185					
Coefficient of correlation.			0·01	0·41*	0·25*	—0·34*	0·63*		—0·10	0·40*	0·10	—0·38*	0·48*		—0·06	0·05	—0·11	—0·38*	0·18*

TABLE 42.

Mean values of specific gravity, percentage butter-fat, solids-not-fat, lactose and crude protein for values of percentage ash increasing at equal intervals.

Buffaloes.

Percentage ash.	Murrah.						Village.					
	No. of samples	Specific gravity.	Percentage fat	Percentage solids-not-fat	Percentage lactose	Percentage crude protein	No. of samples.	Specific gravity.	Percentage fat	Percentage solids-not-fat	Percentage lactose	Percentage crude protein
0·4605	1	1·01855	4·205	5·705	3·105	2·305	1	1·02255	4·605	6·505	3·705	2·305
0·5005	..	..	..	..	..	..	1	1·02155	5·805	6·105	3·105	2·505
0·5405	1	1·02755	5·405	6·705	3·105	2·705	3	1·02722	6·072	7·838	4·015	3·305
0·5805	3	1·02422	4·605	7·038	3·772	2·905	1	1·03355	7·405	9·705	4·905	4·105
0·6205	4	1·02805	6·905	8·505	4·655	3·755	4	1·02655	5·905	8·105	4·405	3·805
0·6605	21	1·03174	7·005	9·019	4·924	3·372	21	1·02979	7·291	8·772	5·010	3·248
0·7005	47	1·03098	6·852	9·262	4·965	3·624	59	1·03033	7·768	9·037	4·980	3·502
0·7405	83	1·03124	7·121	9·175	4·895	3·650	87	1·03153	7·649	9·397	5·066	3·668
0·7805	68	1·03148	7·540	9·237	4·929	3·811	111	1·03176	7·495	9·393	4·963	3·746
0·8205	35	1·03164	7·188	9·414	4·808	3·894	96	1·03215	7·718	9·478	4·913	3·886
0·8605	26	1·03136	7·559	9·436	4·490	4·228	57	1·03188	7·847	9·523	4·866	3·972
0·9005	11	1·03164	7·587	9·305	4·378	4·287	26	1·03201	8·620	9·805	4·751	4·405
0·9405	3	1·03322	6·872	10·038	4·705	4·238	13	1·03332	6·882	9·751	4·690	4·320
0·9805	..	..	..	..	..	..	11	1·03291	7·478	10·105	4·778	4·505
1·0205	1	1·03455	6·605	10·505	4·705	4·505	4	1·03430	5·205	11·055	4·905	4·755
1·0605	3	1·03088	5·538	8·572	3·438	5·105	..	..	..	.	..	..
1·1005	1	1·03455	6·205	10·905	4·505	5·305	..	..	..	..	..	..
1·1405	..	..	.	..	..	..	..	..	..	..	..	.
1·1805	..	..	..	..	..	..	..	..	..	..	..	..
1·2205		.	..	..	..	..	1	1·03455	7·805	9·905	4·505	4·505
Total . .	308	..	..	..	..	..	496					
Coefficient of correlation.		0·25*	0·13	0·36*	—0·16*	0·56*		0·38*	0·06	0·52*	—0·06	0·58*

COWS

Red Sindhi
Hostein Sindhi
Village

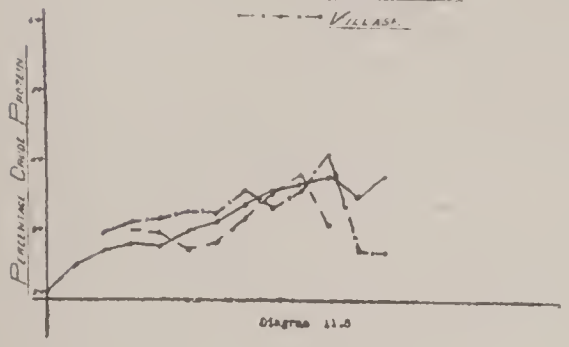


Diagram 11.5

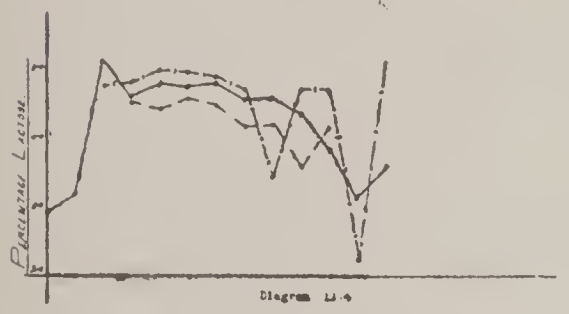


Diagram 11.6

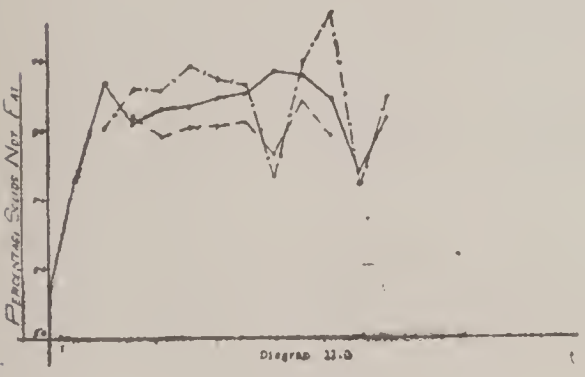


Diagram 11.7

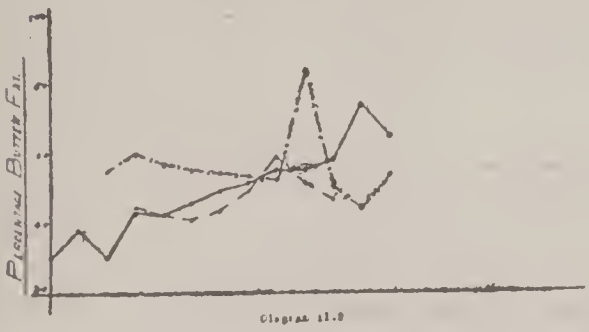


Diagram 11.8

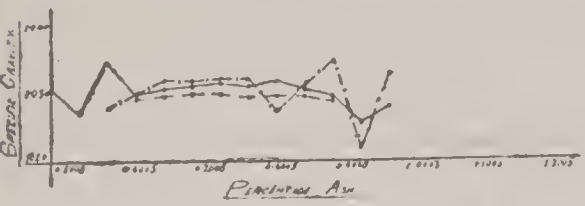


Diagram 11.9

Table No 41

BUFFALOES

Murrah
Village

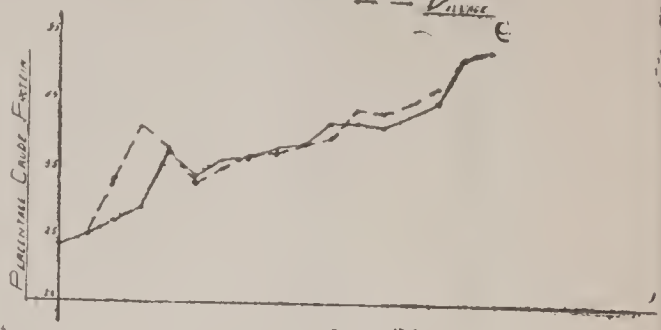


Diagram 12.5

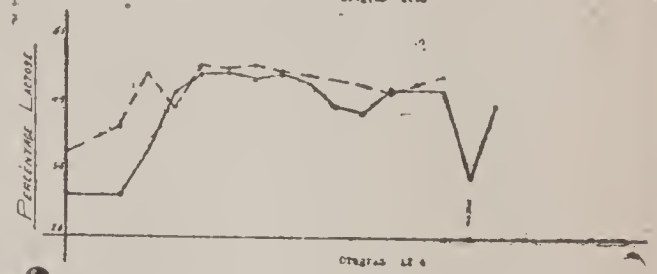


Diagram 12.6

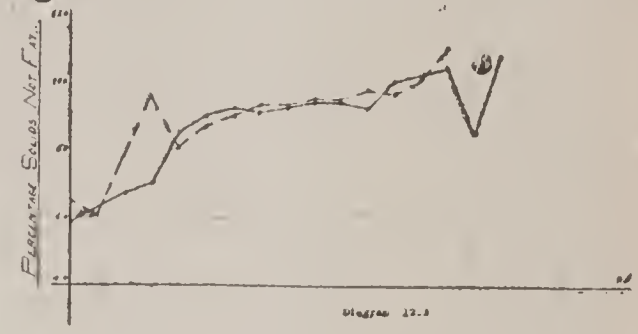


Diagram 12.7

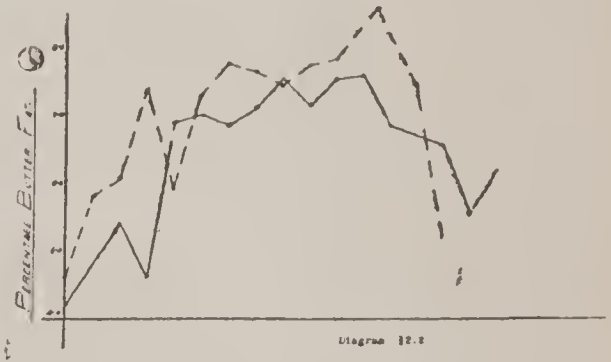


Diagram 12.8

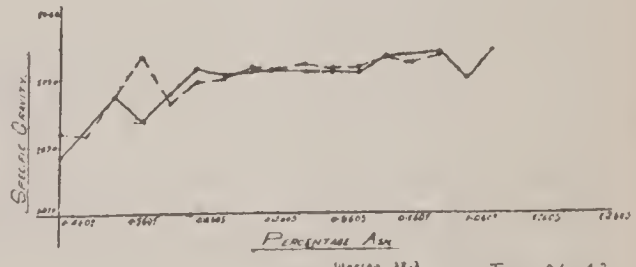


Diagram 12.9

Table No 42

TABLE 43.

Mean values of specific gravity, percentage butter fat, solids-not-fat, lactose, ash and casein for values of crude protein increasing at equal intervals.

Cows.

Percentage crude protein.	Red Sindhi.							Holstein Sindhi.							Village.						
	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage casein.	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage casein.	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage casein.
2·105	1	1·03055	3·005	5·705	2·905	0·5005	..	..	..	..	..	..	..	..	1	1·02055	3·805	5·905	2·105	0·9405	..
2·305	3	1·02888	4·205	8·305	4·705	0·6338	1·705(1)	5	1·02955	3·805	7·820	4·665	0·7165	1·705(1)	2	1·02955	5·205	8·005	4·305	0·7405	2·305(1)
2·505	21	1·02998	4·015	8·019	4·734	0·6757	1·772(3)	31	1·02955	3·908	8·002	4·608	0·7147	1·869(11)	1	1·02755	3·005	7·505	3·905	0·7005	..
2·705	72	1·03033	4·199	8·200	4·772	0·6977	2·013(13)	40	1·02983	4·025	7·975	4·615	0·7135	2·013(13)	6	1·02922	4·338	8·372	4·872	0·7738	2·205(4)
2·905	91	1·03022	4·614	8·243	4·635	0·7286	2·187(17)	29	1·02976	4·302	8·174	4·491	0·7253	2·180(8)	25	1·02895	5·533	8·273	4·809	0·6861	2·280(8)
3·105	126	1·03116	4·751	8·461	4·710	0·7246	2·353(29)	28	1·02905	4·605	8·041	4·112	0·7534	2·288(12)	53	1·02989	5·375	8·543	4·841	0·7128	2·438(9)
3·305	102	1·03107	5·056	8·801	4·581	0·7554	2·505(22)	13	1·02986	5·159	8·351	4·305	0·7651	2·505(2)	29	1·02879	5·681	8·560	4 650	0·7226	2·672(6)
3·505	76	1·03097	5·447	8·642	4·439	0·7868	2·691(14)	20	1·02865	5·385	8·255	4·005	0·7645	2·465(5)	29	1·03024	5·929	8·884	4·850	0·7377	2·805(4)
3·705	42	1·03131	5·729	8·848	4·481	0·8062	2·791(7)	1	1·03155	5·805	6·705	4·305	0·8205	..	14	1·03176	6·319	9·119	4·876	0·7233	3·005(4)
3·905	33	1·03097	6·011	8·802	4·172	0·8193	2·772(3)	1	1·02855	7·405	8·305	3·305	0·8605	..	10	1·03275	5·645	9·205	4·865	0·7405	3·105(1)
4·105	13	1·03132	5·990	8·905	4·213	0·7590	3·205(4)	2	1·03005	4·005	8·405	3·405	0·7605	..	6	1·03338	6·538	9·605	4·972	0·8005	3·305(2)
4·305	4	1·03405	5·305	9·155	4·205	0·8705	..	1	1·02955	5·005	7·705	4·505	0·8205	..	6	1·03438	5·805	9·772	4·838	0·7472	3·505(1)
4·505	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1·03555	4·605	10·505	5·105	0·7805	..
4·705	2	1·03305	6·005	9·905	4·505	0·8605	3·705(1)	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	586						(114)	171						(52)	183						(40)
Coefficient of correlation.		0·17*	0·57*	0·47	−0·29*	0·63*	0·90*		−0·13	0·54*	0·19*	−0·56*	0·48*	0·86*		0·37*	0·21*	0·60*	0·16*	0·18*	0·90*

N.B.—Figures in brackets indicate the number of samples for percentage casein.

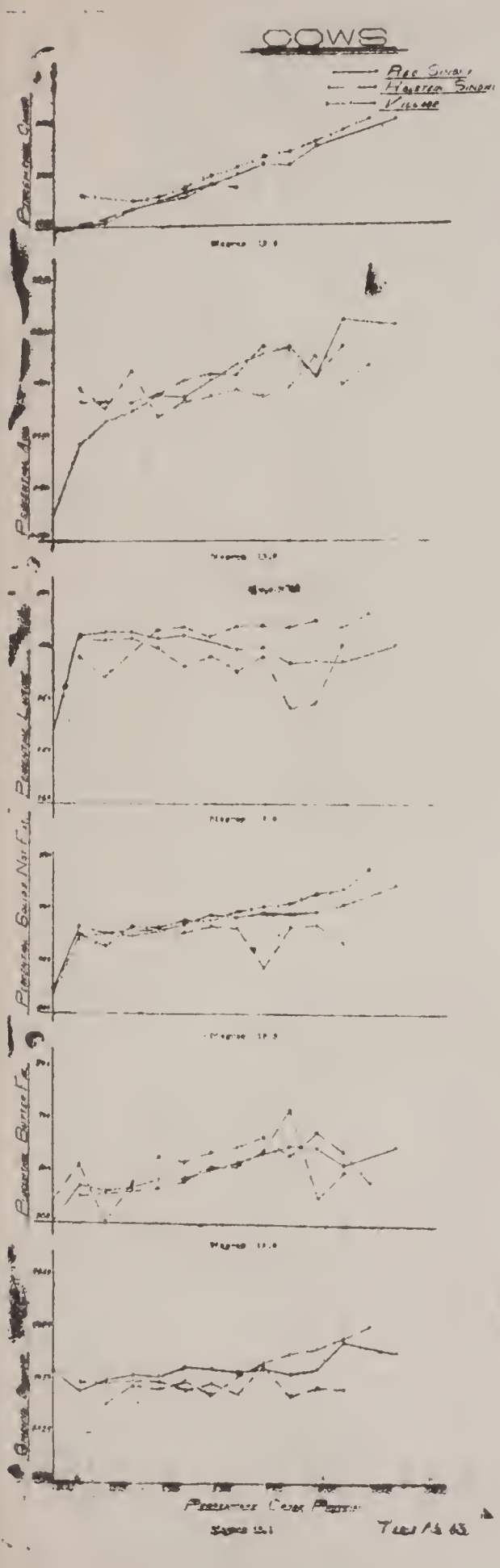
TABLE 44.

Mean values of specific gravity, percentage butter-fat, solids-not-fat, lactose, ash and casein for values of percentage crude protein increasing at equal intervals.

Buffaloes.

Percentage crude protein.	Murrah.							Village.						
	No. of samples.	Specific gravity.	Percentage fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage casein.	No. of samples.	Specific gravity.	Percentage fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage casein.
2·305	1	1·01855	4·205	5·705	3·105	0·4605	..	1	1·02255	4·605	6·505	3·705	0·4605	..
2·505	1	1·03155	6·205	9·105	4·905	0·7405	2·905(1)	1	1·02155	5·805	6·105	3·105	0·5005	.
2·705	1	1·02755	5·405	6·705	3·105	0·5405	..	4	1·02780	5·305	7·655	4·555	0·6705	2·305(1)
2·905	5	1·02635	5·325	7·905	4·305	0·6365	..	11	1·02800	6·314	8·341	4·760	0·6605	2·505(3)
3·105	15	1·03015	6·498	8·652	4·412	0·7592	2·465(5)	21	1·03122	6·472	8·962	5·134	0·7367	2·505(4)
3·305	51	1·02814	6·566	8·838	4·913	0·7287	2·634(14)	55	1·03100	7·281	9·327	5·065	0·7310	2·720(13)
3·505	46	1·03207	6·649	9·322	5·053	0·7318	2·905(5)	85	1·03169	7·094	9·244	5·070	0·7640	2·893(16)
3·705	65	1·03135	6·987	9·203	4·887	0·7651	2·979(19)	94	1·03154	7·609	9·365	4·956	0·7933	2·993(25)
3·905	46	1·03138	7·414	9·179	4·788	0·7701	3·155(12)	86	1·03213	7·572	9·484	4·996	0·8052	3·116(18)
4·105	31	1·03110	8·153	9·440	4·731	0·7792	3·334(7)	52	1·03190	8·282	9·694	4·901	0·7997	3·319(14)
4·305	21	1·03160	8·472	9·495	4·800	0·8015	3·455(4)	35	1·03152	8·536	9·659	4·754	0·8365	3·425(5)
4·505	9	1·03077	8·961	9·638	4·349	0·8872	3·505(1)	22	1·03064	9·714	9·823	4·496	0·8696	.
4·705	5	1·03235	7·725	9·945	4·623	0·9085	..	15	1·03302	8·552	10·158	4·652	0·8738	.
4·905	1	1·03455	7·405	9·705	4·505	0·8605	..	6	1·03372	7·938	10·172	4·772	0·9272	..
5·105	3	1·03288	8·205	10·305	4·238	0·9005	..	3	1·03522	6·205	10·505	4·705	0·9405	3·805(2)
5·305	4	1·03405	7·705	10·355	4·205	0·9705	4·105(1)	1	1·03555	6·205	10·705	4·105	0·8805	..
5·505	2	1·02805	9·405	9·805	3·205	0·8605	..	2	1·03355	6·605	11·105	4·305	0·9805	..
5·705	..	..	..	..	..	..	..	1	1·02655	11·805	8·505	2·505	0·9005	..
5·905	..	..	..	..	.	.	..	..	..	..	.	.	..	..
6·105	1	1·03055	6·605	10·905	4·105	0·7005	..	1	1·03855	5·405	10·505	5·105	0·9005	..
Total	308						(69)	496						(101)
Coefficient of correlation		0·18*	0·46*	0·55*	−0·23*	0·56*	0·88*		0·26*	0·34*	0·57*	0·25*	0·58*	0·89*

N.B.—Figures in brackets indicate the number of samples for percentage casein.


COWS
Red Sindhi
Hariana Sindhi
Village
Percentage Cream
Percentage Ash
Percentage Lactose
Percentage Solids Not Fat
Percentage Butter Fat
Specific Gravity
Percentage Cream Present
Plate No 45

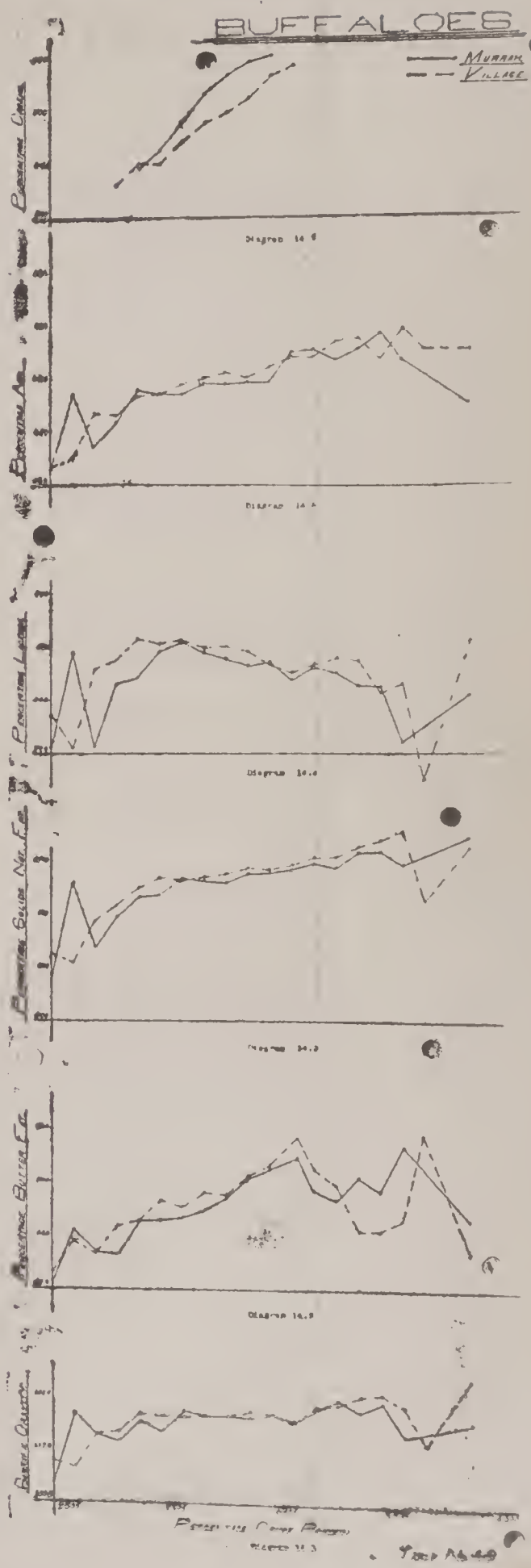

BUFFALOES
Murrah
Village
Percentage Cream
Percentage Ash
Percentage Lactose
Percentage Solids Not Fat
Percentage Butter Fat
Specific Gravity
Percentage Cream Present
Plate No 46

TABLE 45.

Mean values of specific gravity, percentage butter fat, solids-not-fat, lactose, ash and crude protein for values of percentage total solids increasing at equal intervals.

Cows.

Percentage total solids.	Red Sindhi							Holstein Sindhi.							Village						
	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not fat.	Percentage lactose.	Percentage ash.	Percentage crude protein.	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not fat.	Percentage lactose.	Percentage ash.	Percentage crude protein	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage crude protein.
8·305	2	1·02555	3·005	5·305	2·505	0·6405	2·505														
9·605	3	1·02455	3·158	6·638	3·438	0·6338	2·705								2	1·02255	3·605	6·205	2·305	0·8805	2·805
10·405	4	1·02555	3·305	6·955	3·605	0·6605	2·605	2	1·02905	2·805	7·605	4·405	0·6805	2·505	1	1·02855	3·005	7·505	3·905	0·7005	2·505
11·205	11	1·02946	3·296	7·869	4·232	0·7150	3·032	22	1·02996	3·535	7·805	4·523	0·7132	2·596	3	1·02688	3·672	7·438	3·572	0·7805	3·038
12·005	70	1·03086	3·834	8·219	4·731	0·7079	2·811	62	1·02981	4·011	8·005	4·466	0·7244	2·815	11	1·02973	4·023	7·886	4·378	0·7732	3·069
12·805	167	1·03102	4·468	8·390	4·689	0·7388	3·006	51	1·02920	4·558	8·121	4·399	0·7362	2·991	22	1·03064	4·460	8·396	4·650	0·7187	3·076
13·605	174	1·03107	5·012	8·554	4·581	0·7506	3·266	18	1·02949	5·094	8·338	4·249	0·7693	3·238	35	1·03129	4·914	8·694	4·939	0·6982	3·122
14·405	83	1·03090	5·569	8·712	4·517	0·7872	3·474	12	1·02847	5·972	8·421	4·072	0·7605	3·338	43	1·03204	5·517	8·933	4·896	0·7238	3·405
15·205	45	1·03111	6·232	8·869	4·527	0·7992	3·607	3	1·02955	6·872	8·238	4·238	0·7672	3·438	35	1·03089	6·399	8·819	4·905	0·7165	3·388
16·005	20	1·03155	6·765	9·135	4·535	0·8105	3·935	1	1·02855	7·405	8·305	3·305	0·8605	3·905	24	1·03118	7·021	8·963	4·905	0·7272	3·563
16·805	4	1·02855	7·905	8·755	4·105	0·8305	3·905								7	1·03112	7·576	9·048	5·623	0·7462	3·534
17·605	2	1·02955	8·005	9·705	4·205	0·8005	3·705								2	1·03205	7·605	9·905	5·005	0·7605	4·205
13·405	1	1·02755	9·005	9·105	4·505	0·7805	3·705								1	1·03255	9·405	9·505	4·505	0·8605	4·505
Total .	586							171							186						
Coefficient of correlation.		0·16*	0·87*	0·58*	0·01	0·44*	0·68*		—0·21*	0·84*	0·38*	—0·31*	0·40*	0·60*		0·25*	0·86*	0·54*	0·40*	—0·08	0·50*

Table 46.

Mean values of specific gravity, percentage butter fat, solids-not-fat, lactose, ash and crude protein for values of percentage total solids increasing at equal intervals.

Buffaloes.

Percentage total solids.	Murrah							Village						
	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage crude protein.	No. of samples.	Specific gravity.	Percentage butter fat.	Percentage solids-not-fat.	Percentage lactose.	Percentage ash.	Percentage crude protein.
9·805	2	1·01955	4·005	5·605	2·305	0·7605	2·805							
10·405	2	1·02355	3·605	6·605	2·905	0·7405	3·105							
11·205	..	..	..	..	..	..	..	1	1·02255	4·605	6·505	3·705	0·4605	2·305
12·005	3	1·02755	4·605	7·305	3·438	0·6338	3·105	2	1·02255	5·405	7·205	3·305	0·5605	2·705
12·805	1	1·02455	5·805	7·305	4·105	0·5805	2·905	4	1·02780	5·005	7·705	4·205	0·7205	2·980
13·605	3	1·02855	5·405	8·372	4·638	0·6738	3·305	8	1·03066	5·055	8·530	4·780	0·6855	3·080
14·405	18	1·03194	5·716	8·805	5·038	0·7583	3·416	20	1·03235	5·445	8·975	5·035	0·7545	3·385
15·205	48	1·03155	6·130	9·105	4·988	0·7572	3·447	47	1·03272	5·984	9·301	5·152	0·7958	3·565
16·005	82	1·03205	6·683	9·307	4·946	0·7571	3·659	95	1·03268	6·534	9·461	4·981	0·7961	3·760
16·805	79	1·03154	7·395	9·373	4·864	0·7658	3·827	105	1·03195	7·424	9·396	5·017	0·7778	3·718
17·605	29	1·03148	8·026	9·519	4·753	0·7874	4·115	111	1·03147	8·119	9·471	4·993	0·7928	3·829
18·405	23	1·03072	8·901	9·409	4·714	0·7718	4·175	46	1·03101	8·848	9·509	4·927	0·7892	3·944
19·205	5	1·02955	9·455	9·380	4·655	0·8255	4·355	17	1·02955	9·829	9·470	4·646	0·8064	4·164
20·005	4	1·02750	10·905	8·855	4·005	0·8105	4·055	22	1·02955	10·387	9·596	4·441	0·8478	4·478
20·805	4	1·02755	10·905	9·605	4·055	0·8605	4·705	10	1·02855	11·605	9·325	4·205	0·8165	4·425
21·605	1	1·02255	12·205	9·505	2·505	0·8805	5·505	6	1·02922	11·538	9·972	4·672	0·8472	4·605
22·405	1	1·02855	12·605	9·505	4·105	0·8605	5·305	2	1·02555	12·805	9·805	3·905	0·8205	4·505
Total	308							496						
Coefficient of correlation		0·04	0·89*	0·51*	0·03	0·26*	0·62*		—0·26*	0·92*	0·31*	—0·23*	0·25*	0·54*

Diagrams (15·1) and (16·1) showing the regression of specific gravity on total solids suggest that the regressions are different in the different groups of cows and buffaloes. Moreover the regression seems to be non-linear in the case of buffaloes. As regards the intensity of association there seems to be a slight negative association between the two factors in the case of Holstein Sindhi cows and a slight positive association in other groups, but the correlations are all very small and non-significant.

With the percentage butter fat the total solids content show a very high relationship. Part of the relationship is of course of a spurious nature. The relationship is linear in type and of about the same intensity in all groups. The correlation is of the order of 0·9.

Part of the correlation of total solids with solids-not-fat is also spurious. The correlation is less than with butter fat and is of the order of 0·5.

The correlation of the total solids with lactose is unstable. It is seen to be positive in village cows and negative in Holstein Sindhi cows. In other groups it is small and non-significant. The instability in the degree of relationship as measured by the coefficient of correlation is possibly due to the non-linear character of regression.

Ash content and total solids content show a small positive association in all except the village group of cows. The association is seen to be a little more marked in cows' than in buffaloes' milk. The correlations are of the order of 0·25 in buffaloes and 0·42 in Red Sindhi and Holstein Sindhi cows.

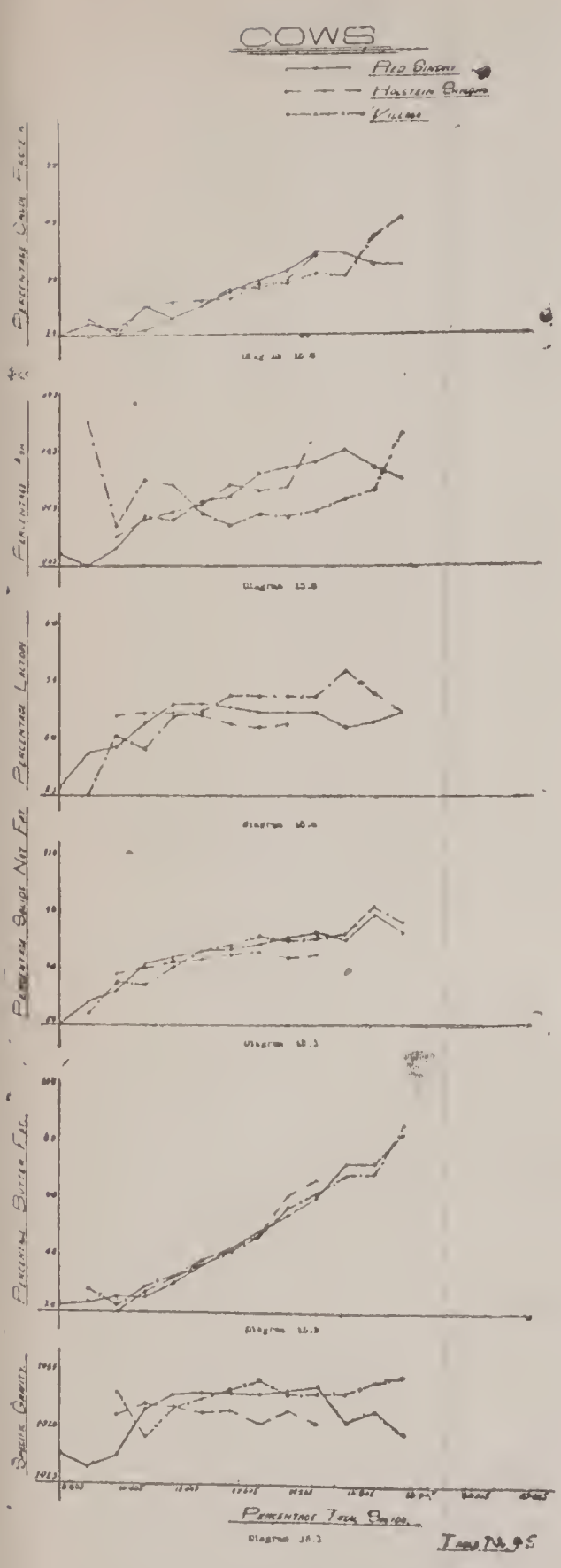
With crude protein there seems to be a high positive relationship part of which is also spurious. The regression is linear. The correlation is of the order of 0·6.

Freezing point depression and other factors.

The correlation coefficient between the various factors considered above and the freezing point depression are shown in Table 30. As the number of freezing point determinations were few, no regression table or diagrams are given. The coefficients have been calculated only for the records of the Red Sindhi cows and the village group of buffaloes; other groups had too few freezing point determinations. Even for the Red Sindhi group of cows and the village buffaloes the number of samples of milk, on which freezing point has been determined, are only 78 and 95 respectively.

It will be seen from the table that there is no significant association between the freezing point depression with any of the factors.

The freezing point as a method of detecting added water in milk is considered to be of value by some workers. With a view to determine how the freezing point depression is affected by the addition of water, double distilled water was added in different quantities to samples of milk and the freezing point depression of the samples thus diluted was determined. Table 47 shows the number of samples diluted with different quantities of double distilled water and their freezing point depression values. It will be seen that the freezing point depression decreases with the addition of distilled water. The last two columns of the table show the values of the coefficient of regression of the freezing point depression on the percentage of distilled water, and their standard errors. It will be seen that the regression coefficients are more or less equal for all the groups of cows and buffaloes. The regression coefficients indicate that for the addition of each percentage of double distilled water the freezing point depression decreases on the average by 0·005.


COWS
Red Sindhi
Hariana Bulls
Kulas
Percentage Solids Not Fat
Percentage Solids
Percentage Butter Fat
Specific Gravity
Percentage Total Solids
Table No. 45

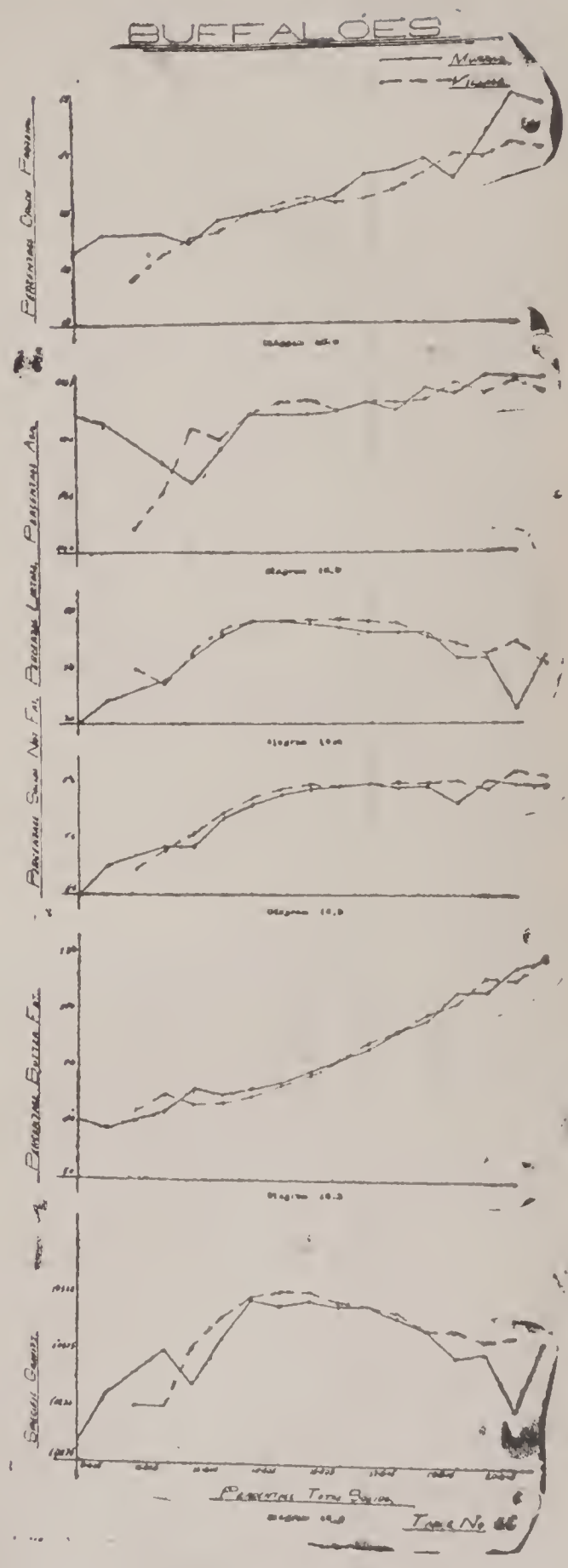
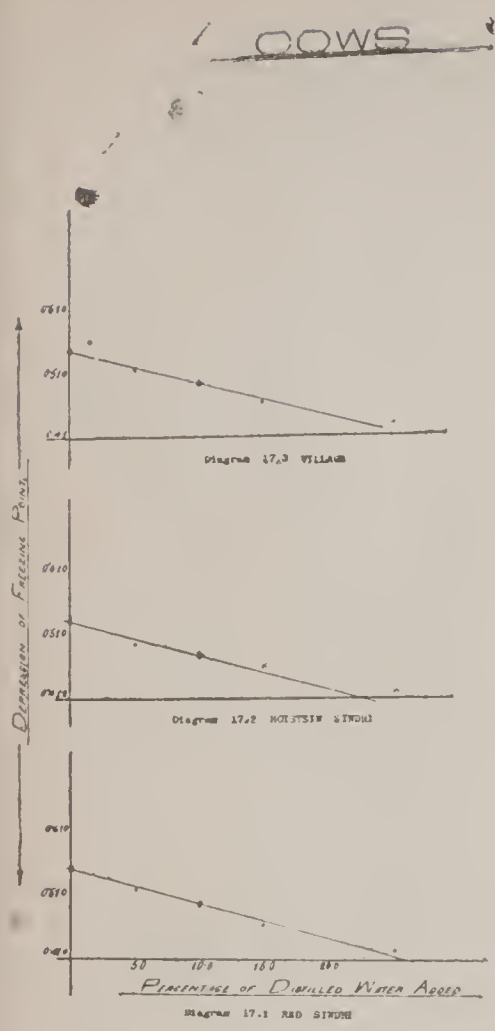

BUFFALOES
Murrah
Nili
Percentage Total Solids
Table No. 46

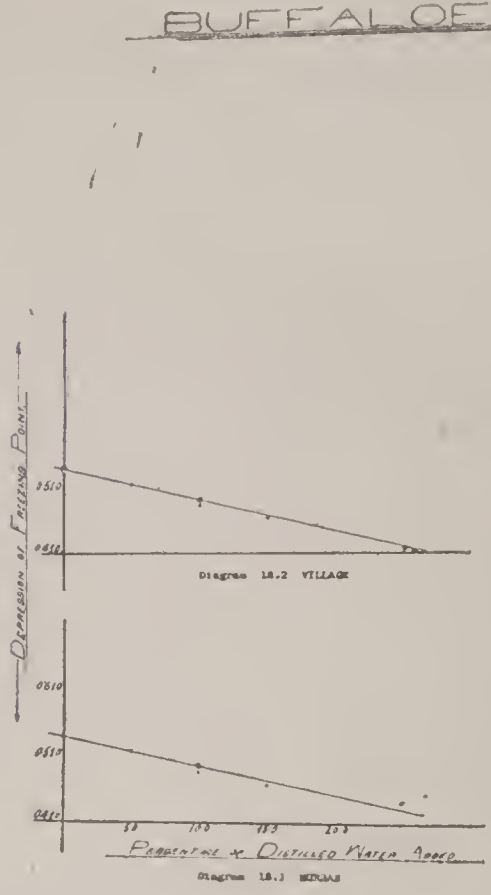
TABLE 47

Value of freezing point depression in samples diluted with double distilled water.

(Figures in brackets show the numbers of samples.)

Group.	No. of animals.	Whole undiluted milk.	5%	10%	15%	25%	Coefficient of regression.	Standard error.
Red Sindhi cows	6 (45)	0·5430 (14)	0·5176 (9)	0·4915 (10)	0·4706 (8)	0·4238 (4)	0·0048	·0002
Holstein Sindhi cows	2 (12)	0·5333 (6)	0·5013 (3)	0·4800 (3)	0·4583 (3)	0·4183 (3)	0·0046	·0003
Village cows	4 (26)	0·5469 (9)	0·5183 (4)	0·4936 (5)	0·4633 (4)	0·4300 (4)	0·0048	·0001
Murrah buffaloes	5 (37)	0·5432 (11)	0·5156 (7)	0·4859 (7)	0·4665 (8)	0·4400 (4)	0·0043	·0003
Village buffaloes	12 (98)	0·5398 (34)	0·5117 (15)	0·4819 (15)	0·4601 (15)	0·4184 (19)	0·0049	·0001





7. INFLUENCE OF THE PERIOD OF LACTATION AND OF SEASON ON THE YIELD OF MILK, ITS SPECFIC GRAVITY AND MAIN CONSTITUENTS

The study of the influence of the period of lactation and of season is much more difficult than is apparent since the influences of the two factors are intermixed and require to be separated for individual evaluation. Thus the variation in the average values of a constituent for different months of lactation is not wholly due to the influence of the advance of lactation but is also influenced by season, *e.g.*, the average value of a constituent for the first month after calving may be the average of values which are recorded in, say, the winter months of the year and that for the 6th month after calving may be the average of values recorded in, say, the summer months of the year. In this case it is obvious that the average values for the first month and the sixth month after calving are not comparable since we are not sure whether the summer months have the same influence as the winter months on that constituent. Similarly the variation in the mean values for different months of the year are also affected by the months after calving in which the values are recorded. It is therefore, clear that the influence of either factor can be evaluated only when the calvings are uniformly distributed over the whole year.

There is also another factor which must be taken into account in the study. The influence of season may well vary from one month of lactation to another; conversely the influence of the period of lactation may change from month to month of the year. In other words, there may be interaction between the two factors.

It has not been possible for us to study this question in detail. Following the customary way we have only worked out the average values of the yield of milk, its specific gravity and main constituents for each month of the lactation for each group of animals and described the variations in each character with the advance in lactation. As regards the influence of season we have confined ourselves to the study of records of the Red Sindhi Group where alone calvings are fairly uniformly distributed over each year.

In studying the effect of season we examined the data separately for each month of lactation but found that the seasonal influence varied, often irregularly, from one month of lactation to another. We thought it, therefore, advisable to discuss only the average effect, over all months of lactation, on the various characters. Data for each month of lactation illustrating the influence of season are rather voluminous and are not included in the report. Instead we have given table 48, showing the influence of season, averaged over all months of calving, on the various characters.

TABLE 48

Mean values of milk yield, specific gravity and percentages of main constituents for each calendar month

RED SINDHI COWS

Months	No. of observations	Milk yield	Specific gravity	Percentage total solids	Percentage butter fat	Percentage solids-not-fat	Percentage lactose	Percentage ash	Percentage crude protein
		oz.							
January	53	181·2	1·03112	13·830	5·141	8·652	4·656	0·7843	3·349
February	52	174·2	1·03108	13·439	4·865	8·573	4·691	0·7468	3·143
March	58	153·8	1·03097	13·574	5·032	8·541	4·668	0·7579	3·186
April	53	170·5	1·03145	13·312	4·822	8·453	4·738	0·7430	3·176
May	48	142·1	1·03085	13·545	5·187	8·360	4·517	0·7486	3·254
June	53	141·6	1·03075	13·237	4·859	8·355	4·480	0·7515	3·139
July	39	118·2	1·02985	13·358	5·111	8·240	4·232	0·7499	3·243
August	37	170·1	1·03041	13·614	5·176	8·438	4·449	0·7563	3·205
September	39	194·6	1·03085	13·141	4·850	8·291	4·602	0·7314	3·085
October	47	218·0	1·03126	13·443	4·820	8·683	4·669	0·7743	3·237
November	56	212·8	1·03117	13·332	1·722	8·601	4·700	0·7478	3·231
December	51	177·3	1·03094	13·459	4·841	8·618	4·575	0·7530	3·265

Milk Yield (Table 49 ; Diagrams 19·1 and 20·1).

The variation in the milk yield with the advance in lactation is distinctly different in Red Sindhi, Holstein Sindhi and Village cows. The milk yield shows a small increase in the first two months of lactation in the case of Holstein Sindhi cows but decreases thereafter. In the case of Red Sindhi and Village cows, however, no initial increase is recorded, the monthly averages of milk yield showing a fall from the beginning. The milk yield range varies from 84·4 oz. to 421·2 oz. in Holstein Sindhi cows, 57·2 oz. to 262·4 oz. in Red Sindhi cows and 24·0 oz. to 87·2 oz. in village cows. The influence of the period of lactation on the yield of milk is similar in Murrah and the village buffaloes. It is difficult to say from the monthly figures if the milk yield shows a tendency to increase in the first month but there seems to be a gradual fall from the first month onwards throughout the lactation period. The range goes from 54·0 oz. to 239·7 oz. in the Murrah group of buffaloes and from 20·0 oz. to 155·7 oz. in the village buffaloes.

TABLE 49

Average Daily Milk Yield in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein Sindhi		Village		Murrah		Village	
	No. of samples	Daily milk yield oz.	No. of samples	Daily milk yield oz.	No. of samples	Daily milk yield oz.	No. of samples	Daily milk yield oz.	No. of samples	Daily milk yield oz.
1	58	262·4	18	388·7	30	87·2	28	235·0	58	155·7
2	62	246·3	17	413·9	28	86·6	35	239·7	65	144·8
3	63	225·1	20	424·2	31	66·6	32	204·4	66	145·1
4	56	199·6	16	356·1	24	50·2	29	174·6	69	127·8
5	60	167·7	17	357·1	22	44·1	31	170·6	57	117·2
6	50	152·8	18	279·6	18	45·9	30	158·2	50	110·0
7	48	142·3	18	229·7	17	31·9	28	146·4	43	85·9
8	49	127·4	15	209·0	9	26·0	22	137·3	30	74·6
9	43	111·8	11	160·7	1	32·5	15	112·0	20	90·3
10	34	100·6	13	98·6	2	34·0	16	114·8	10	84·0
11	20	100·6	5	84·4	1	24·0	14	111·4	5	65·6
12	15	97·2	..	..	..	..	8	108·3	5	51·6
13	11	90·4	..	..	..	..	7	38·3	3	56·0
14	10	81·4	..	..	..	..	5	76·8	4	30·0
15	5	57·2	..	..	..	..	5	54·8	3	29·3
16	2	64·0	..	..	..	..	1	64·0	2	24·0
17	..	..	..	..	..	..	2	54·0	1	20·0
Total	586	..	171	..	186	..	308	..	491	..

The behaviour of the milk yield with the advance in lactation is somewhat masked by the monthly averages as compared with the daily records. Consequently it is difficult to determine accurately the regression of the milk yield on the days of lactation. The question is, however, being studied separately on the basis of data available at Allahabad. From the figure, it seems that the trend is linear in Red Sindhi and village cows but is of a cubic form in the case of Holstein Sindhi cows. In the Murrah group the regression appears to be parabolic.

Study of the influence of season on the records of the Red Sindhi cows shows that the yield of milk tends to be somewhat low during the summer and the monsoon months. As we have already said such study is not possible on the records of other group since the calvings in their case have not been distributed uniformly over all months of the year.

Specific Gravity (Table 50 ; Diagrams 19·2 and 20·2). The specific gravity decreases in the first month of lactation. From the first month onwards the behaviour of specific gravity with the advance in lactation is different in the different groups. It seems to be more or less stationary upto the sixth month of lactation but decreases gradually thereafter in the case of Holstein Sindhi cows but shows a somewhat irregular behaviour in the case of Red Sindhi and village cows. However, no great weight can be attached to the behaviour after the sixth month of lactation since the average values in the later months of lactation are based on relatively fewer observations. In buffaloes the behaviour is distinctly different from that observed in the case of cows, but is similar in Murrah and village buffaloes. There is a steep drop in the first month of lactation but from the second month onwards the fall is gradual though increasingly irregular with the advance in lactation. The range of variation is from 1·02797 to 1·03038 in the Holstein Sindhi group, from 1·03007 to 1·03320 in Red Sindhi cows and from 1·02973 to 1·03285 in village cows. In buffaloes of the Murrah group the range goes from 1·02762 to 1·03387 while in village buffaloes it varies from 1·02670 to 1·03434.

As regards the effect of season on the specific gravity table 18 shows that the specific gravity tends to be low during the period May to September.

TABLE 50

Mean Specific Gravity of Milking different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein-Sindhi		Village		Murrah		Village	
	No. of samples	Specific Gravity	No. of samples	Specific Gravity	No. of samples	Specific Gravity	No. of samples	Specific Gravity	No. of samples	Specific Gravity
1	58	1·03167	18	1·03038	30	1·03285	28	1·03390	58	1·03434
2	62	1·03083	17	1·02985	28	1·03185	35	1·03183	65	1·03259
3	63	1·03101	20	1·03006	31	1·03185	32	1·03191	66	1·03210
4	56	1·03109	16	1·02985	21	1·03037	29	1·03172	69	1·03171
5	60	1·03107	17	1·02986	22	1·03039	31	1·03215	57	1·03138
6	50	1·03064	18	1·02995	18	1·03019	30	1·03176	59	1·03125
7	48	1·03069	18	1·02976	17	1·02980	28	1·03131	43	1·03022
8	49	1·03110	15	1·02923	9	1·03099	22	1·02924	30	1·03094
9	43	1·03087	14	1·02851	1	1·03065	15	1·03148	20	1·02921
10	34	1·03037	13	1·02825	2	1·02950	16	1·03056	10	1·03082
11	20	1·03039	5	1·02797	1	1·03039	14	1·02913	5	1·03112
12	15	1·03007	..	..	.	..	8	1·03038	5	1·02886
13	11	1·03098	.	..	.	.	7	1·02836	3	1·02900
14	10	1·03105					5	1·02836	1	1·02970
15	5	1·03112					3	1·02762	1	1·02817
16	2	1·03320					1	1·02900	2	1·02670
17	.						1	1·02860	1	1·02930
Total	586	..	171		135		308		491	

Percentage butter fat (Table 51 ; Diagrams 19·3 and 20·3).

The influence of the period of lactation on the percentage of butter fat is different in Holstein Sindhi, Red Sindhi and village cows. In the Holstein Sindhi group the percentage butter fat decreases upto the third month, remains somewhat stationary from the third to the seventh month and then increases rapidly. In Red Sindhi cows the percentage butter fat decreases upto the second month of lactation but begins to increase immediately afterwards. As against this the percentage of butter fat in the milk of village cows seems to increase from the beginning. In buffaloes the percentage of butter fat seems to increase almost from the beginning of lactation. The range goes from 4·031 to 6·287 in Holstein Sindhi cows and from 4·292 to 6·439 and from 4·523 to 6·915 in Red Sindhi and village cows respectively. In buffaloes the range is even larger going from 6·096 to 9·350 in Murrahs and from 6·029 to 11·525 in village buffaloes.

There does not seem to be any clear indication of seasonal effect on butter fat percentage in the milk of Red Sindhi cows.

TABLE 51

Mean Percentage of Butter-Fat in milk in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein-Sindhi		Village		Murrah		Village	
	No. of samples	Butter-fat percent	No. of samples	Butter-fat percent	No. of samples	Butter-fat percent	No. of samples	Butter-fat percent	No. of samples	Butter-fat percent
1	58	4·567	18	4·479	30	4·523	28	6·116	58	6·029
2	62	4·292	17	4·058	28	4·725	35	6·343	65	6·630
3	63	4·601	20	4·031	31	5·698	32	6·476	66	7·276
4	56	4·869	16	4·143	24	5·739	29	6·849	60	7·547
5	60	4·778	17	4·116	22	5·964	31	7·039	57	7·851
6	50	4·987	18	3·978	18	6·352	30	7·141	50	8·053
7	48	4·894	18	4·244	17	6·257	28	7·249	43	8·807
8	49	5·097	15	4·686	9	6·729	22	7·699	30	8·651
9	43	5·264	14	4·821	4	6·783	15	7·914	20	8·565
10	34	5·718	13	5·188	2	7·040	16	8·162	10	8·011
11	20	5·666	5	6·287	1	6·450	14	8·498	5	9·246
12	15	5·545	..	..	..	..	8	8·466	5	9·914
13	11	5·744	..	..	..	..	7	8·560	3	10·733
14	10	5·670	..	..	..	..	5	8·118	4	11·525
15	5	6·430	..	..	..	..	5	9·020	3	10·683
16	2	5·860	..	..	..	..	1	9·100	2	9·500
17	..	..	..	..	..	..	2	9·350	1	10·800
Total .	586	..	171	..	186	..	308	..	491	..

Percentage solids-not-fat (Table 52 ; Diagrams 19·4 and 20·4).

The behaviour of the percentage of solids-not-fat with the advance in lactation is much more irregular than that of fat. The behaviour is similar upto about the fourth month of lactation in all the three groups of cows and similar in the Red Sindhi and Holstein-Sindhi cows even in the later months. The percentage of solids-not-fat shows a steep fall in the first two months of lactation in all the groups but the fall continues even in the third month in the village and Holstein Sindhi cows. The range of fall goes from 8·001 to 8·491 in Holstein Sindhi cows from 8·119 to 8·812 in Red Sindhi cows and from 8·571 to 9·145 in village cows. Unlike percentage butter fat, however , it does not show any definite increase in the later months. The percentage of solids-not-fat seems to be less at the end of lactation than in the beginning. In buffaloes' milk also the behaviour is irregular but more or less similar to that seen in the case of cows' milk. The percentage solids-not-fat shows a steep fall of 0·622 in Murrah buffaloes and of 0·478 in village ones upto the second month of lactation ; thereafter it tends to rise upto the sixth month, then it tends to fall upto the eighth month and again shows a rise in the subsequent months. The behaviour though somewhat irregular is more or less, similar in Murrah and village buffaloes.

The percentage of solids-not-fat in Red Sindhi cows' milk tends to be lower than the average during the months April to September and higher during the other months, *i.e.*, October to March.

TABLE 52

Mean percentage of Solids-not-fat in the milk in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein-Sindhi		Village		Murrah		Village	
	No. of samples	Solids-not-fat percent	No. of samples	Solids-not-fat percent	No. of samples	Solids-not-fat percent	No. of samples	Solids-not-fat percent	No. of samples	Solids-not-fat percent
1	58	8·812	18	8·191	30	9·145	28	9·801	58	9·870
2	62	8·419	17	8·201	28	8·759	35	9·183	65	9·392
3	63	8·468	20	8·301	31	8·571	32	9·222	66	9·354
4	56	8·507	16	8·491	24	8·641	29	9·348	69	9·345
5	60	8·490	17	8·061	22	8·729	31	9·381	57	9·426
6	50	8·421	18	8·067	16	8·521	30	9·269	50	9·370
7	48	8·321	18	7·901	17	8·411	28	9·111	43	9·288
8	49	8·413	15	8·021	9	8·618	22	8·687	30	9·082
9	43	8·692	11	8·104	4	8·630	15	9·291	20	8·832
10	34	8·378	13	7·912	2	8·645	16	9·353	13	9·167
11	20	8·518	5	7·750	4	8·470	14	9·050	5	9·350
12	15	8·363	..	..	..	..	8	9·668	5	9·130
13	11	8·662	..	..	..	..	7	8·691	3	9·223
14	10	8·575	..	..	..	..	5	8·426	4	9·355
15	5	8·736	..	..	..	..	5	8·716	3	9·227
16	2	8·925	..	..	..	..	1	9·180	2	8·240
17	..	..	..	..	..	..	2	9·200	1	9·461
Total .	586	..	171	..	186	..	308	..	491	..

Percentage total solids (Table 53 ; Diagrams 19·5 and 20·5).

The percentage of total solids shows a fall upto the second month of lactation in Red Sindhi and village cows but decreases upto the third month of lactation in Holstein Sindhi cows. It rises somewhat steeply in the month following the month of peak value. From the fourth month onwards, it tends to decrease in the case of Red Sindhi and Holstein Sindhi cows but increases gradually from the seventh month onwards. In village cows, however, the percentage of total solids tends to increase from the second month onwards. The range of variation is very different in the three groups. It goes from 12·027 to 13·123 in the Holstein Sindhi group, from 12·712 to 15·166 in the Red Sindhi group, and from 13·465 to 15·112 in the village cows. The behaviour with the advance in lactation is similar upto the seventh month both in the Murrah and the village buffaloes, but is irregular thereafter possibly due to the fewness of observations. The range varies from 15·525 to 18·550 in the Murrah group and from 15·899 to 20·260 in the village buffaloes.

Table 48 does not show that season has any clearcut effect on the percentage of total solids in milk.

TABLE 53

Mean percentage of total solids in milk in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein-Sindhi		Village		Murrah		Village	
	No. of samples	Total Solids percent	No. of samples	Total Solids percent	No. of samples	Total Solids percent	No. of samples	Total Solids percent	No. of samples	Total Solids percent
1	58	13·409	18	13·014	30	13·811	28	15·920	58	15·899
2	62	12·711	17	12·137	28	12·465	35	15·526	65	16·022
3	63	13·069	20	12·027	31	11·302	32	15·730	66	16·639
4	56	13·375	16	12·324	24	11·338	29	16·197	69	16·941
5	60	13·268	17	12·177	22	11·635	31	16·421	57	17·277
6	50	13·409	18	12·045	18	11·872	30	16·410	50	17·362
7	48	13·217	18	12·115	17	11·671	28	16·360	43	18·096
8	49	13·510	15	12·689	9	15·346	22	16·386	30	17·733
9	43	13·866	14	12·926	4	15·113	15	17·205	20	17·397
10	34	14·096	13	13·123	2	15·685	16	17·511	13	17·178
11	20	14·184	5	12·967	1	14·920	14	17·548	5	18·590
12	15	15·908	.	..	..	.	8	18·131	5	19·044
13	11	14·405	..	..	.	..	7	17·161	3	19·957
14	10	14·215	..	.	.	.	5	16·511	1	20·880
15	5	15·166	.	.	.	.	5	17·736	3	19·910
16	2	14·785	.	.	.	.	1	18·280	1	17·710
17	..	.	.	.	.	.	2	18·550	1	20·260
Total .	586	..	171	..	186	..	308	..	491	.

Percentage Lactose (Table 54; Diagrams 19·6 and 20·6).

The percentage of lactose in the milk of Holstein Sindhi and village cows tends to increase in the beginning and falls thereafter. The maximum is attained in the third month of lactation in the Holstein Sindhi group and in the second month in village cows. In the case of Red Sindhi cows the percentage of lactose shows a decrease from the beginning. The behaviour is somewhat irregular in the later months of lactation in all the three groups but might possibly be ascribed to the fewness of observations. The range varies greatly from group to group; it goes from 3·624 to 4·670 in the Holstein Sindhi group; from 4·291 to 4·776 in the Red Sindhi group and from 4·455 to 4·970 in the village cows. The behaviour of percentage of lactose in buffaloes' milk is different from that observed in the case of cows' milk. The peak value is reached in the second month of lactation in the case of Murrah group and in the third month of lactation in the case of village buffaloes. From the second to the sixth month the percentage of lactose is more or less stationary but from the sixth month onwards it shows a fall in both Murrah and village buffaloes. The range is about the same in both groups going from 4·142 to 5·070 in the Murrah group and from 3·695 to 5·052 in the village buffaloes.

The four months May to August appear to have a depressing effect on the percentage of lactose in the milk of Red Sindhi cows. The percentage remains slightly above the average during the rest of the year.

TABLE 54

Mean percentage of Lactose in milk in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red Sindhi		Holstein Sindhi		Village		Murrah		Village	
	No. of samples	Lactose percent	No. of samples	Lactose percent	No. of samples	Lactose percent	No. of samples	Lactose percent	No. of samples	Lactose percent
1	58	4·776	18	4·501	30	4·826	28	4·727	58	4·937
2	62	4·768	17	4·552	28	4·970	35	5·061	65	4·989
3	63	4·756	20	4·570	31	4·864	32	5·021	65	5·052
4	56	4·713	16	4·552	24	4·782	29	4·977	69	5·016
5	60	4·591	17	4·495	22	4·842	31	5·070	57	5·044
6	50	4·547	18	4·454	18	4·717	39	5·008	50	5·004
7	48	4·455	18	4·267	17	4·463	28	4·675	43	4·865
8	40	4·545	15	4·271	9	4·672	22	4·428	30	4·753
9	43	4·491	14	4·147	4	4·678	15	4·821	20	4·695
10	34	4·374	13	3·959	2	4·620	16	4·670	10	4·695
11	29	4·353	5	3·624	1	4·520	14	4·459	5	4·688
12	15	4·491	..	..	..	..	8	4·684	5	4·356
13	11	4·291	..	..	..	..	7	4·319	3	4·440
14	10	4·406	..	..	..	..	5	4·188	4	4·170
15	5	4·420	..	..	..	..	5	4·142	3	4·167
16	4	4·410	..	..	..	..	1	4·580	2	3·695
17	..	..	..	..	..	..	2	4·370	1	4·369
Total	586	..	171	..	186	..	308	..	491	..

Percentage Ash (Table 55; Diagrams 19·7 and 20·7).

In all the groups of cows the percentage of ash decreases upto the second month of lactation but tends to rise in the later months until in the sixth month it is higher than at the beginning. The behaviour is naturally irregular after the sixth month. The range goes from 0·709 to 0·796 in the Holstein Sindhi group; from 0·721 to 0·842 in the Red Sindhi group and from 0·683 to 0·743 in the village cows. In buffaloes there is a steep fall in the first month but, unlike the case of cows' milk the percentage of ash does not show a tendency to rise in later months; but is more or less stationary. The large fluctuations in the last months of lactation are due to the very few observations on which the averages are based.

The percentage of ash in the milk of Red Sindhi cows appears to be definitely higher than the average during the four months October to January. During the rest of the year it fluctuates about the average value.

TABLE 55

Mean percentage of Ash in milk in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein-Sindhi		Village		Murrah		Village	
	No. of samples	Ash per cent	No. of samples	Ash per cent	No. of samples	Ash per cent	No. of samples	Ash per cent	No. of samples	Ash per cent
1	58	0·7550	18	0·7356	29	0·7339	28	0·8647	58	0·8664
2	62	0·7206	17	0·7091	28	0·7049	35	0·7813	65	0·7813
3	63	0·7284	20	0·7168	31	0·7099	32	0·7546	66	0·7883
4	56	0·7304	16	0·7323	24	0·7299	29	0·7491	69	0·7759
5	60	0·7556	17	0·7332	22	0·7306	31	0·7627	57	0·7747
6	50	0·7668	18	0·7333	18	0·7365	30	0·7438	50	0·7773
7	48	0·7598	18	0·7455	17	0·7380	28	0·7545	43	0·7673
8	49	0·7609	15	0·7365	9	0·7342	22	0·7424	30	0·7896
9	43	0·7686	14	0·7501	4	0·7298	15	0·7553	20	0·7639
10	34	0·7549	13	0·7372	2	0·6995	16	0·7573	10	0·7963
11	20	0·7762	5	0·7960	1	0·7080	14	0·7594	5	0·7518
12	15	0·7601	..	..	..	..	8	0·7684	5	0·7324
13	11	0·7835	..	..	..	..	7	0·7187	3	0·7530
14	10	0·7771	..	..	..	..	5	0·6910	4	0·8160
15	5	0·7864	..	..	..	..	5	0·7890	3	0·8400
16	2	0·8420	..	..	..	..	1	0·7900	2	0·7570
17	..	..	..	..	..	..	2	0·7940	1	0·8508
Total	586	..	171	..	185	..	308	..	191	..

Percentage crude protein (Table 56; Diagrams 19·8 and 20·8).

The percentage of crude protein tends to decrease in the beginning. The minimum is reached in the third month of lactation in the case of Holstein Sindhi cows and in the second month of lactation in the case of Red Sindhi and village cows. From the month in which the minimum value is attained the percentage of crude protein gradually increases until in about the ninth month of lactation it shows a higher value than at the beginning. In buffaloes the behaviour is more or less similar to that in cows. The minimum is reached in the third month of lactation in the case of Murrah buffaloes and in the second month of lactation in the case of village buffaloes.

Similar to the percentage of ash the percentage of crude protein in Red Sindhi cows' milk appears to be definitely above the average during the four months October to January. During the other months it fluctuates about the average.

TABLE 56

Mean percentage of Crude Protein in milk in different months after calving.

Month after calving	COWS						BUFFALOES			
	Red-Sindhi		Holstein-Sindhi		Village		Murrah		Village	
	No. of samples	Crude Protein per cent	No. of samples	Crude Protein per cent	No. of samples	Crude Protein per cent	No. of samples	Crude Protein per cent	No. of samples	Crude Protein per cent
1	58	3·316	18	3·040	29	3·445	28	4·249	58	4·101
2	62	2·907	17	2·799	28	3·148	35	3·568	65	3·638
3	63	3·028	20	2·682	31	3·253	32	3·518	66	3·649
4	56	3·089	16	2·789	24	3·260	29	3·681	69	3·719
5	60	3·183	17	2·791	21	3·343	31	3·504	57	3·761
6	50	3·167	18	2·824	18	3·301	30	3·664	50	3·811
7	48	3·207	18	2·988	17	3·367	28	3·823	43	3·781
8	49	3·244	15	3·075	9	3·376	22	3·714	30	3·804
9	43	3·384	14	3·153	3	3·760	15	3·813	20	3·675
10	34	3·360	13	3·267	2	3·480	16	3·868	10	3·870
11	20	3·510	5	3·224	1	3·450	14	4·035	5	4·104
12	15	3·420	..	..	..	..	8	4·193	5	4·084
13	11	3·634	..	..	..	..	7	3·797	3	4·270
14	10	3·523	..	..	..	..	5	3·694	4	4·505
15	5	3·734	..	..	..	..	5	3·948	3	4·313
16	2	4·030	..	..	..	..	1	3·840	2	3·950
17	..	..	..	..	..	..	2	4·260	1	4·540
Total	586	..	171	..	183	..	308	..	491	..

8. PREDICTION OF THE PERCENTAGE SOLIDS-NOT-FAT FROM THE OBSERVED VALUES OF THE SPECIFIC GRAVITY AND THE PERCENTAGE BUTTER FAT

A formula known after Richmond (30) given as

$$S = \cdot 25G + \cdot 20\ F + \cdot 14$$

where S = percentage solids-not-fat, G = 1000 (specific gravity − 1) and F = percentage butter fat, is widely used for determining the percentage of solids-not-fat in a sample of milk from a knowledge of its specific gravity and the percentage butter fat content. The formula has been deduced by Richmond on certain assumptions relating to the constancy of the specific gravity, of butter fat and solids-not-fat content of milk. The actual derivation of the formula does not concern us here. Our purpose is to investigate whether its application under Indian conditions can be regarded as a substitute for the direct laboratory method, and, if not, what error is involved in the predicted value.

In order to test the applicability of this formula, we have calculated, for each of the several samples of milk, the values of the percentage solids not-fat by substituting in the formula the observed values of the percentage butter fat and the specific gravity and have compared those with the corresponding observed values for solids-not-fat obtained by the direct laboratory method. We have found that sometimes the observed value of the solids-not-fat content was less than the Richmond's value, sometimes larger, but in the long run, in each of the several groups of cows and buffaloes, we found that the Richmond's value was larger than the observed value in more than half the number of samples. The comparison clearly showed that the Richmond's formula cannot be considered as a substitute for the laboratory method but that at best it may be considered as a means of predicting only approximately the solids-not-fat content of milk.

[To face page 74.

COWS

Red Sindhi

Holstein Sindhi

Village

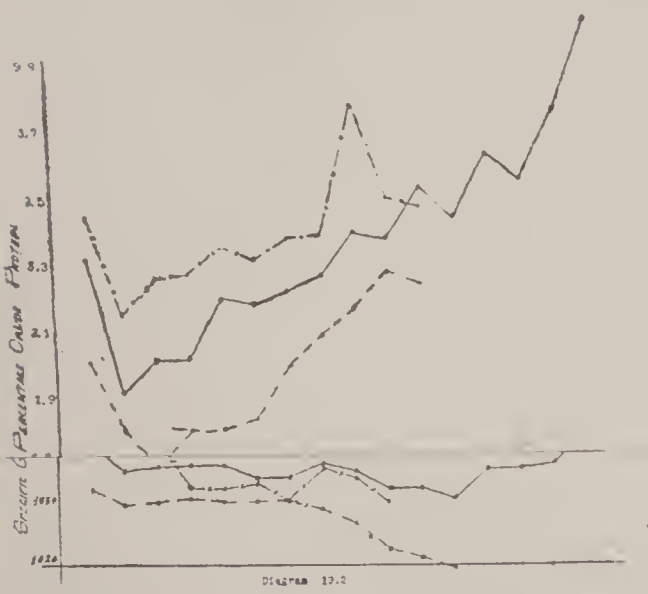


Diagram 19.2

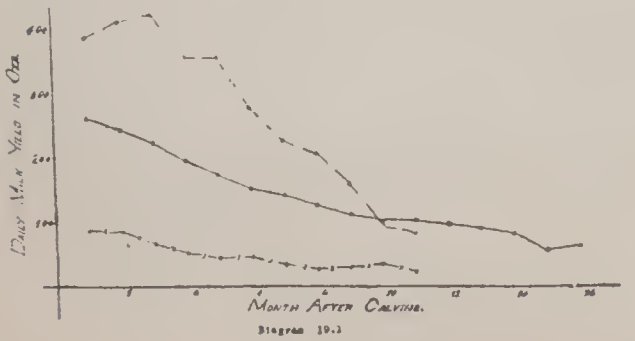


Diagram 19.3

BUFFALOES

Murrah

Village

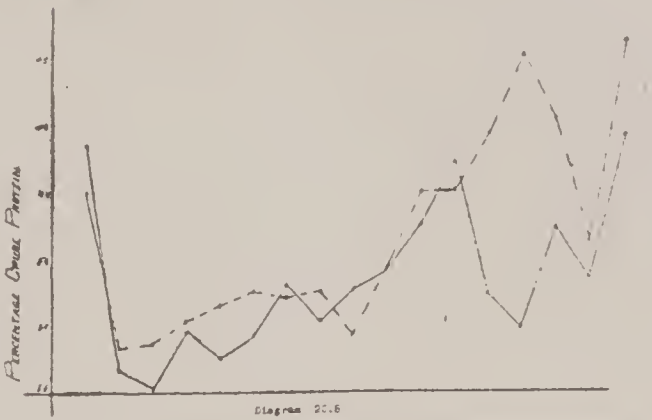


Diagram 20.6

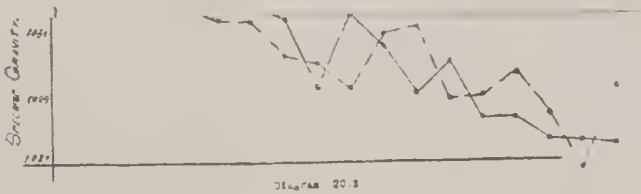


Diagram 20.5

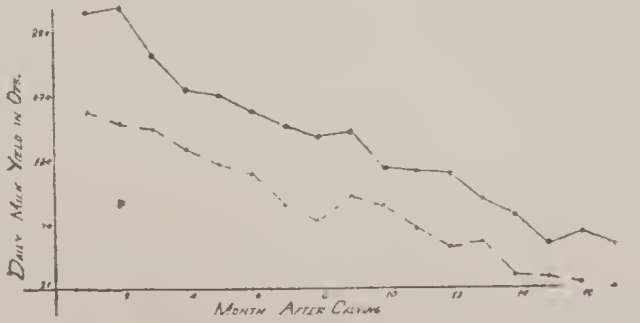


Diagram 20.4

TABLE 57

Frequency distributions of the differences between the observed vaules of solids-not-fat and those deduced from Richmand's Formula

Differences	Cows			Buffaloes	
	Red-Sindhi	Holstein-Sindhi	Village	Murrah	Village
Less than —1·00	12	7	9	9	15
,, — ·95	6	..	1	..	1
,, — ·90	7	1	4	4	2
,, — ·85	10	2	2	..	4
,, — ·80	7	1	4	3	3
,, — ·75	10	5	5	2	2
,, — ·70	21	5	1	4	18
,, — ·65	7	4	4	5	12
,, — ·60	23	9	5	10	9
,, — ·55	23	7	6	11	15
,, — ·50	43	8	9	7	15
,, — ·45	46	10	8	7	27
,, — ·40	51	17	13	21	27
,, — ·35	40	12	13	20	36
,, — ·30	49	22	10	20	35
,, — ·25	43	10	16	27	30
,, — ·20	32	7	10	14	37
,, — ·15	27	9	17	14	28
,, — ·10	24	8	10	16	27
,, — ·05	19	6	12	13	18
,, 0·00	16	2	5	15	19
,, + ·05	10	2	4	14	11
,, + ·10	9	4	4	8	14
,, + ·15	9	1	4	10	10
,, + ·20	8	1	3	6	7
,, + ·25	11	1	..	9	9
,, + ·30	3	2	1	3	7
,, + ·35	3	..	3	5	8
,, + ·40	1	1	1	7	2
,, + ·45	..	1	..	3	3
,, + ·50	..	1	..	4	5
,, + ·55	..	..	..	2	6
,, + ·60	..	..	1	1	3
,, + ·65	1	..	.	..	2
,, + ·70	..	..	..	..	4
,, + ·75	1	1	..	1	4
,, + ·80	2	..	..	..	5
,, + ·85	..	..	..	..	1
,, + ·90	..	..	..	2	1
,, + ·95	..	.	..	1	1
,, +1·00	1	..	..	..	1
Greater than 1·00	2	4	1	10	12
Total	586	171	186	308	496
Mean	—0·348	—0·320	—0·319	—0·162	—0·169
Standard deviation	0·36	0·49	0·42	0·51	0·47

Table 57 shows the frequency distributions of the differences in samples of milk between the observed values of the percentage solids-not-fat and those deduced from Richmond's formula for each of the several groups of cows and buffaloes. The table clearly brings out the fact that on the average Richmond's formula over-estimates the solids-not-fat content of milk. If Richmond's formula was unbiassed for India, we would expect the mean value of the frequency distributions to be zero; actually we see that the mean values are near about —·33 for cows' milk and —0·17 for buffaloes' milk. In other words, on the average, Richmond's formula over-estimates the percentage solids-not-fat content of cows' milk by 0·33 percent and of buffaloes' milk by 0·17 per cent. It will be noted that the bias observed is of the same order in different groups of cows and in different groups of buffaloes.

The extent to which a frequency distribution of the differences is spread out gives a measure of the accuracy of prediction. Obviously the more the spread of a frequency distribution the more is the error of the predicted value and vice versa. It will be seen that the range of variation extends beyond —1·0 on the lower side of the mean value and +1·0 on the upper side of the mean value. In other words, it shows that we may occasionally get a value for the percentage of solids-not-fat differing from the true mean value by more than —1·0 or +1·0, but the frequency of getting a discrepancy as large or larger is very small. The extent of spread is measured by the standard deviation whose values

are shown in the last line of the table. A value twice that of the standard deviation gives a measure of discrepancy likely to arise in a random sample. It will be seen that the standard deviation is roughly ·4 for cows' milk and ·5 for buffaloes' milk. In cows' milk we may thus expect a discrepancy from the true value upto a limit of $-0{\cdot}33 \pm 2\times(0{\cdot}4)$ or roughly 0·5 to 1·1 and in buffaloes' milk upto a limit of $-0{\cdot}17 \pm 2\times(0{\cdot}5)$ or roughly 0·8 and 1·2.

It will be noticed that if, in the Richmond's formula, we reduce the constant term by the bias observed or, in other words, we use the following equations.

S=·25 G +·20 F —·19 for cows and

S=·25 G +·20 F —·03 for buffaloes

in place of the original Richmond's equation, we shall be able to estimate the percentage solids-not-fat content with an error which will rarely exceed 0·8 in cows' milk and 1·0 in buffaloes' milk.

Tocher in his excellent report on the variations in the composition of milk puts a question whether a prediction formula with a smaller error can be devised and proceeds to derive one with the help of what is known as the regression method in statistics. The principle underlying the method is to minimise the spread of the frequency distribution of the differences between the observed and the regression values so that the predicted value will differ the least from the true solids-not-fat content of milk. This is done by minimising the sum of the squares of the differences. The method assumes that there is a linear association between the proportion of the solids-not-fat and the specific gravity and also between the proportion of solids-not-fat and the proportion of butter fat. If S, $\bar{G}$, and $\bar{F}$ denote the mean values of the variables S, G and F already defined; S_s, S_g and S_f their standard deviations and r_{sg}, r_{gf} and r_{sf} denote the coefficients of correlation between S and G, G and F, and S and F respectively then it can be shown that the equation of prediction which has the minimum error is given by the following

$$S-\bar{S}=\frac{r_{sg}-r_{sf}\,r_{gf}}{1-r_{gf}^2}\,\frac{S_s}{S_g}(G-\bar{G})+\frac{r_{sf}-r_{sg}r_{gf}}{1-r_{gf}^2}\,\frac{S_s}{S_f}(F-\bar{F})$$

On substituting the values of the means, the standard deviations and the coefficients of correlation for each of the several groups of cows and buffaloes in the above, the following regression equations for predicting the percentage solids-not-fat of milk from a knowledge of the specific gravity and the percentage of butter fat are obtained

S=·208G+·182F+1·182 for Red Sindhi Cows
S=·0724G+·0154F+5·875 for Holstein-Sindhi Cows;
S=·216G+·124F+1·307 for Village cows;
S=·180G+·138F+2·605 for Murrah buffaloes;
S=·206G+·139F+1·815 for village buffaloes.

It will be observed that the regression equation for Holstein Sindhi cows is markedly different from those for other groups. There is no significant difference between the coefficients of G and F in the equations for Red Sindhi and village cows; likewise there is no significant difference in the coefficients of G and F for the Murrah and the village buffaloes. The values of the constant term in these equations however differ significantly from one another. It will also be observed that the coefficients of G and F in the Richmond's formula are significantly larger than those in the regression equations; the constant term on the other hand is significantly smaller in the Richmond's formula.

In order to ascertain to what extent these formula are an improvement over the Richmond's formula, we have worked out from these regression equations the values of the percentage of solids-not-fat in different samples for each of the several groups of cows and buffaloes and compared those with the actual observed values. Table 58 shows the frequency distributions of the differences between the observed values and the predicted values. It will be seen that unlike in the case of Richmond's formula these distributions are centred around zero showing that the regression equations give an unbiassed estimate of the solids-not-fat content of milk. It will also be seen that the error attached to the predicted value obtained from the regression equations is a little smaller than in the Richmond's formula. The actual values of the standard deviation are 0·46 for the Murrah and village buffaloes against the corresponding value of 0·51 and 0·47 in the Richmond's formula; 0·31 for the Red Sindhi group, 0·41 for the Holstein Sindhi group and 0·36 for the village group of cows against the corresponding values of 0·35, 0·49 and 0·42 in the Richmond's formula. It will, however, be noticed that differences in the values of the standard deviations are not large.

TABLE 58

Frequency distribution of the differences between the observed values of solids-not-fat content and the corresponding values deduced from regression equations

Differences	Cows			Buffaloes	
	Red-Sindhi	Holstein-Sindhi	Village	Murrah	Village
Less than —1·00	2	3	5	8	7
,, — ·95	..	..	..	1	3
,, — ·90	1	1	..	..	..
,, — ·85	2	..	..	2	..
,, — ·80	1	..	..	1	2
,, — ·75	2	1	1	3	1
,, — ·70	1	..	..	2	2
,, — ·65	2	..	2	1	3
,, — ·60	1	..	1	1	7
,, — ·55	6	..	1	4	5
,, — ·50	10	3	4	4	8
,, — ·45	7	3	4	4	19
,, — ·40	11	7	6	6	12
,, — ·35	14	4	8	13	16
,, — ·30	21	8	3	10	18
,, — ·25	18	10	5	11	20
,, — ·20	23	10	8	12	30
,, — ·15	28	7	6	24	38
,, — ·10	37	12	10	28	40
,, — ·05	50	11	9	20	26
,, — ·00	54	15	19	20	40
,, + ·05	52	8	15	22	30
,, + ·10	50	11	15	12	19
,, + ·15	38	10	6	10	20
,, + ·20	30	12	10	15	12
,, + ·25	26	3	9	14	14
,, + ·30	19	8	7	9	11
,, + ·35	21	2	10	7	18
,, + ·40	10	3	3	4	5
,, + ·45	6	5	8	8	9
,, + ·50	9	1	2	3	7
,, + ·55	8	2	1	2	4
,, + ·60	7	1	..	7	9
,, + ·65	5	2	1	2	6
,, + ·70	3	1	1	1	2
,, + ·75	1	..	1	1	2
,, + ·80	2	1	..	3	7
,, + ·85	1	1	1	1	3
,, + ·90	0	0	1	..	4
,, + ·95	1	..	..	..	..
,, +1·00	..	1	..	..	..
Greater than +1·00	6	4	2	12	17
Total	586	171	186	308	496
Means	—0·004	0·000	—0·002	0·002	—0·010
Standard Deviation	0·31	0·41	0·36	0·46	0·46

We therefore conclude that the regression equations give us a better approximation to the solids-not-fat content of milk than the Richmond's formula but when the latter is corrected for the bias we find that there is no material difference in the accuracy with which solids-not-fat content is determined by the two formulae. On the other hand it is possible that the bias observed in the Richmond's formula may remain of the same order in cows and buffaloes and in that case the Richmond's formula corrected for bias may well be preferred to different regression formulae. Further investigation is, however, clearly necessary to ascertain if the application of the Richmond's formula results in a bias of the same order that has been noticed above.

The success of prediction depends upon the degrees of association of the specific gravity and the percentage of butter fat with the percentage of solids-not-fat in milk. We have already seen that the specific gravity is more closely associated with the solids-not-fat content than is butter fat. It is, therefore, of some interest to ascertain whether a knowledge of butter fat content in addition to the knowledge of specific gravity materially improves the accuracy of the solids-not-fat content of milk. Table 59 shows the reduction in the variance of solids-not-fat content of milk effected by specific gravity alone and specific gravity and butter fat content together. It will be seen that except in the case of Holstein-Sindhi cows which have the least value for the correlation between the specific gravity and the solids-not-fat content, the specific gravity helps to reduce the original variance by over 50 per cent. The knowledge of the specific gravity and the butter fat content together will be seen to reduce the original variance by a significantly larger figure of 58 per cent. Although specific gravity is thus mainly responsible for the success of the prediction, the additional knowledge of butter fat content in milk also serves materially to improve the accuracy of prediction.

TABLE 59

Showing the sampling variance and the residual variances of percentage solids-not-fat

Breed	Sampling variance	Residual variance on removing the portion corresponding to	
		specific gravity alone	specific gravity and butter fat together
Red Sindhi cows	0·283	0·156	0·097
Holstein Sindhi cows	0·186	0·176	0·171
Village cows	0·501	0·181	0·131
Murrah buffaloes	0·442	0·259	0·224
Village buffaloes	0·397	0·250	0·221

9. SUMMARY

THE study, which is the first of its magnitude in India, deals with results of the chemical and physical analysis on 2,092 samples of milk from cows and buffaloes in the herds of the Agricultural Institute and three neighbouring village centres. The animals selected for study were Red Sindhi, Holstein-Sindhi and village cows, and Murrah and village buffaloes from the Agricultural Institute's herd and village animals typical of the Allahabad district from the other three centres. All samples were 24 hour composites taken at fortnightly interval. Whereas previous studies have been mainly concerned with the determination of the main constituents of milk, namely butter fat and solids-not-fat, on comparatively few samples, our study has also covered other constituents and has involved 28,710 determinations over a period of 3 years.

Table 60 given below summarises the results of our study on individual samples in respect of the average composition of milk and the variation in each of the several constituents of milk. The statement shows that excepting chlorine and possibly non-protein nitrogen all other constituents of total solids have a higher content in buffaloes' than in cows' milk. The content of albumin is about equal in the two. The statement also shows that breed has a significant influence on the composition of milk.

It is shown that the average composition of the herd milk is approximately the same as the average of the proportions of constituents in samples of the individual animal's milk but that the variability of the constituents in sample of herd milk is less than that in samples of individual animal's milk. It is shown that approximately the variability diminishes inversely as the number of animals in the herd.

A comparison with values of the percentage of butter fat and solids-not-fat obtained by previous workers shows a fair agreement with our value for the percentage of butter fat but shows a discrepancy with our value for the percentage of solids-not-fat. Certain reasons explaining the discrepancy are suggested in the report.

While the limitations of our data have been recognised it is shown that the existing standards in the provinces for quality of milk are inadequate. In particular, we have reached the conclusion that the existing standard for the percentage of butter fat is a bit too low and that the existing standard for the percentage of solids-not-fat, for cows' milk at any rate, is somewhat high.

The type and intensity of association between the proportions of the various constituents and

TABLE 60

Mean values, standard deviations and percentage coefficients of variation of the percentage constituents and other characters of milk

		Cows				Buffaloes		
		Red Sindhi	Holstefn-Sindhi	Village	All	Murrah	Village	All
Specific gravity	N.	586	171	186	943	308	496	804
	Mean	1·03088	1·02950	1·03104	1·03066	1·03122	1·03156	1·03143
	Stan. Dev.	0·00188	0·00147	0·00274	0·00209	0·00266	0·00242	0·00237
	C. V.	0·18	0·14	0·27	0·20	0·26	0·23	0·23
Fat per cent	N.	586	171	186	943	308	496	804
	Mean	4·925	4·420	5·607	4·968	7·161	7·624	7·446
	Stan. Dev.	0·970	0·888	1·234	1·026	1·375	1·598	1·532
	C. V.	19·7	20·1	21·8	20·7	19·2	21·0	20·6
Solids-not-fat per cent	N.	586	171	186	943	308	496	804
	Mean	8·497	8·079	8·702	8·460	9·215	9·386	9·321
	Stan. Dev.	0·532	0·431	0·708	0·588	0·665	0·630	0·661
	C. V.	6·3	5·3	8·1	6·9	7·2	6·7	7·1
Total Solids per cent	N.	586	171	186	943	308	496	804
	Mean	13·444	12·538	14·302	13·449	16·407	17·002	16·774
	Stan. Dev.	1·204	0·982	1·455	1·337	1·629	1·666	1·675
	C. V.	9·0	7·8	10·1	9·9	9·9	9·8	10·0
Lactose per cent	N.	586	171	186	943	308	496	804
	Mean	4·584	4·393	4·786	4·589	4·809	4·924	4·880
	Stan. Dev.	0·458	0·416	0·562	0·488	0·535	0·426	0·474
	C. V.	10·0	9·5	11·7	10·6	11·1	8·7	9·7
Ash per cent	N.	586	171	185	942	308	496	804
	Mean	0·7516	0·7349	0·7249	0·7433	0·7652	0·7892	0·7800
	Stan. Dev.	0·0692	0·0467	0·0590	0·0647	0·0787	0·0825	0·0818
	C. V.	9·21	6·38	8·08	8·70	10·28	10·45	10·48
Phosphorus Pentoxide per cent.	N.	313	88	79	480	184	272	456
	Mean	0·2351	0·2070	0·2187	0·2272	0·2735	0·2794	0·2770
	Stan. Dev.	0·0500	0·0291	0·0394	0·0477	0·0514	0·0467	0·0486
	C. V.	21·28	14·04	18·00	20·96	18·79	16·70	17·54
Calcium per cent	N.	305	88	78	471	185	263	448
	Mean	0·2112	0·1883	0·2005	0·2051	0·2490	0·2664	0·2592
	Stan. Dev.	0·0427	0·0438	0·0383	0·0431	0·0375	0·0493	0·0482
	C. V.	20·22	23·26	14·10	20·99	15·06	18·51	18·60
Chlorine per cent	N.	324	125	145	594	205	331	536
	Mean	0·0831	0·1113	0·0795	0·0883	0·0671	0·0645	0·0655
	Stan. Dev.	0·0312	0·0277	0·0305	0·0327	0·0220	0·0181	0·0197
	C. V.	37·55	24·80	38·86	37·09	32·82	28·06	30·12
Crude Protein per cent	N.	586	171	183	940	308	496	804
	Mean	3·208	2·934	3·312	3·178	3·768	3·797	3·784
	Stan. Dev.	0·404	0·384	0·409	0·420	0·500	0·502	0·498
	C. V.	12·7	13·1	12·4	13·2	13·8	13·2	13·2
True Protein per cent	N.	109	51	39	199	75	102	177
	Mean	2·855	2·501	3·013	2·798	3·350	3·413	3·386
	Stan. Dev.	0·382	0·321	0·412	0·422	0·412	0·350	0·376
	C. V.	13·4	12·8	13·7	15·1	12·3	10·3	11·1
Non-Protein Nitrogen per cent.	N.	109	51	39	199	75	99	174
	Mean	0·0548	0·0558	0·0503	0·0542	0·0543	0·0479	0·0507
	Stan. Dev.	0·0140	0·0139	0·0125	0·0138	0·0161	0·0152	0·0160
	C. V.	25·63	24·97	24·85	25·45	29·62	31·77	31·50
Casein per cent	N.	114	52	39	205	69	101	170
	Mean	2·419	2·128	2·602	2·380	2·983	3·016	3·003
	Stan. Dev.	0·349	0·237	0·359	0·363	0·269	0·312	0·320
	C. V.	14·4	11·1	13·8	15·3	9·0	10·3	10·7
Albumin per cent	N.	109	50	37	196	68	96	164
	Mean	0·415	0·381	0·392	0·402	0·361	0·401	0·383
	Stan. Dev.	0·154	0·126	0·118	0·141	0·088	0·113	0·099
	C. V.	27·0	33·0	30·0	35·1	24·4	28·1	25·7
Freezing point depression	N.	78	25	32	135	64	95	159
	Mean	0·5454	0·5410	0·5492	0·5455	0·5429	0·5424	0·5426
	Stan Dev.	0·0120	0·0088	0·0132	0·0120	0·0116	0·0103	0·0108
	C. V.	2·20	1·63	2·40	2·20	2·14	1·90	1·99

other characters of milk are discussed. A measure known as the coefficient of correlation is calculated for each of the several pairs of characters. Of particular interest are found the following relationships :—

(1) specific gravity and percentage solids-not-fat,

(2) specific gravity and percentage lactose,

(3) percentage butter fat and percentage crude protein,

(4) percentage butter fat and percentage casein,

(5) percentage lactose and percentage chlorine,

(6) percentage crude protein and percentage casein,

(7) freezing point and the percentage added water.

The influence of the period of lactation and of season on the quality of milk is also discussed.

It is shown that Richmond's scale for predicting the proportion of the solids-not-fat of milk from a knowledge of the specific gravity and the percentage of butter-fat is inapplicable under Indian conditions and certain modifications are suggested.

Owing to the comparatively restricted area to which the data relate and, therefore, to the possibility of greater uniformity arising in the quality of our samples than in the general population, we feel, that in spite of their volume, our data do not provide a sufficient basis for a final consideration of the milk standards and that they should be supplemented by similar investigation all over India. It is not suggested that these supplementary investigations should be as intensive but should be concerned with the determination of only the chief constituents of milk namely, butter fat, and solids-not-fat and also specific gravity. We, however, feel that these investigations should cover much larger geographical areas in order that the samples selected may be representative of the milk supply of the whole province and the results of the investigation be directly applicable to the province concerned. We also suggest that more information on the use of the freezing point as a test of added water should be collected.

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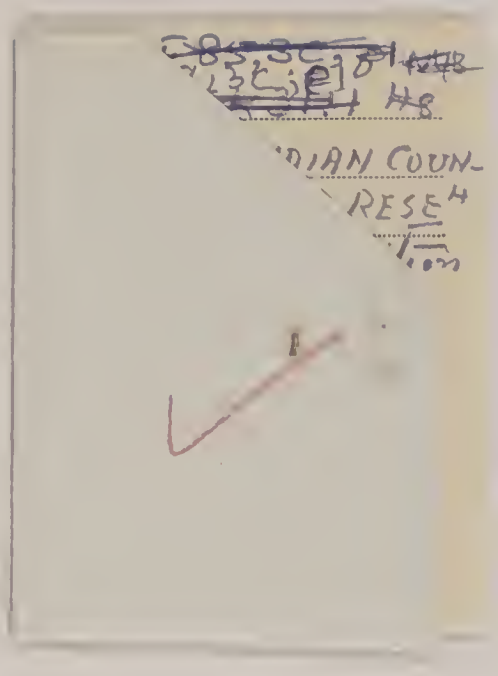
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